

AIR QUALITY TRENDS
IN ONTARIO
1971 - 1982

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Ontario

Ministry
of the
Environment

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AIR QUALITY TRENDS IN ONTARIO
1971 - 1982

Report Number

ARB-131-84-AQM

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Air Quality and Meteorology Section

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Executive Summary

Air quality in Ontario has shown a significant improvement over the years 1971 to 1982 for total suspended particulate matter, particulate lead, soiling index, sulphur dioxide and carbon monoxide. Much of this reduction can be attributed to emission source regulation during the mid-1970's.

Network average sulphur dioxide concentrations were reduced by 68% in the 1972 to 1982 period. Total suspended particulate matter decreased 48% over the 1971-1982 period. Decreases of 31% for 2-hour soiling index and 68% for carbon monoxide were also found for this period as was a decrease in particulate lead of 45%.

Decreases of 22%, 49%, and 41% were found for nitrogen dioxide, nitric oxide and nitrogen oxides, respectively, for the 1976 to 1982 period.

The number and percentage of stations meeting the Ontario criteria for desirable air quality has increased over the period of study. In addition, the total number of exceedences of short term criteria has decreased for many pollutants.

The Ontario monitoring network has grown and been modified over the 1971-1982 period in response to the needs for air quality surveillance across the province. There has also been an increase in the number of chemical species monitored.

Air Quality Trends in Ontario
1971 - 1982

With the passage of the Air Pollution Control Act (1967), the Province of Ontario embarked upon a program of emission source regulation to meet the desirable ambient air quality criteria set forth in the Act. To document the effectiveness of emission regulation, an extensive network of ambient air monitors was established across the Province. Through the years, the network has evolved and been modified in response to the needs of the monitoring program.

From the data collected during the period 1971 to 1982, concentration trends for eleven pollutants have been determined and are presented in this report. In addition, comparisons of data are made with the appropriate desirable ambient air quality criteria and are also reported herein:

1. The Ontario Air Quality Monitoring Network

The regular monitoring of atmospheric pollutants began in Ontario in the early 1960's in the Metropolitan Toronto area. With the passage of the Air Pollution Control Act of 1967, the task of air pollution control was centralized in an agency of the provincial government. At that time, the monitoring program began its expansion across the Province. By the time of the enactment of The Environmental Protection Act in 1971, the number of monitoring instruments had reached 254 for continuous monitoring of gases and total suspended particulate matter. By 1982 the number of instruments was 469 (Figure 1), a growth of 85% in the monitoring network.

The number of monitoring instruments reported in Table 1 reflects the existence of a sensor at a site for a given time in that year. Because of the fluid nature of the network, however, monitoring may begin and/or terminate during a particular year. In order to calculate an annual mean which is meaningful, a minimum number of samples

must be collected. Therefore, for continuous gaseous monitoring and soiling index, only those stations with 75% of the maximum possible hourly observations (8760 hours x 75% = 6570 hours) have been used for trend analysis and comparison with annual criterion. For total suspended particulate matter and particulate lead, stations must have 20 samples with at least 4 per season to be used for calculation of an annual geometric mean. All stations have been used for comparisons with hourly or daily criterion.

2. Ambient Air Quality Criteria in Ontario

The current Ontario criteria for desirable ambient air quality for 7 of the 11 pollutants whose trends are discussed below are given in Table 2. As yet no criteria have been established for total hydrocarbons, nitric oxide, nitrogen oxides, or total reduced sulphur. A guideline for total reduced sulphur of 27 ppb in the vicinity of kraft paper mills has been established. These criteria serve as a convenient yardstick by which the Province may estimate its success in achieving goals for desirable ambient air quality.

Ontario's desirable ambient air quality criteria are based upon the examination of all known effects of the contaminants and are, in terms of time-concentration values, below a concentration known to have significant adverse effect on man, animals, vegetation, or property. The percentage of stations meeting each criterion is treated below by individual pollutant as is the total number of criterion exceedences.

3. Graphical Display of Air Quality Trends

The concentration trends for each of 11 pollutants are analyzed in this study. To visually present the information representing the distribution of air quality data, two graphical techniques are employed.

The first technique is the double-arrow plot which is employed for data years with 2 to 11 reporting stations. This technique is illustrated in Figure 2a. The double-arrow plot displays the maximum annual mean, ensemble average, and minimum annual mean concentration for the number of stations reporting (n). The maximum and minimum are self explanatory. The ensemble average (a) is calculated by

$$a = \frac{1}{n} \sum_{i=1}^n m_i \quad (1)$$

where m_i is the annual mean of the i th station, n is the number of stations and \sum indicates the summation of all m_i from 1 to n .

The second display technique is known as the box plot. The plotting convention for the box plot is displayed in Figure 2b. For a given pollutant, the annual mean of all eligible stations are grouped and then ranked. From this ranking, the 10, 25, 50 (median), 75, and 90 percentile levels are determined. These indicate the percentage of stations cleaner than the plotted value. For example, if the 25 percentile is 17 units, 25% of the stations measuring this pollutant have an annual mean less than 17 units. The ensemble average of the stations (equation 1) in a given year is also plotted. The box plot is used whenever 12 or more stations report means in a given year.

The 10 and 25 percentiles typify the trend of the "cleaner" sites in the sample. The average and median may be thought of as depicting average sites, while the 75 and 90 percentiles typify the "dirtier" sites - those with the highest annual means. Note, however, that these descriptive terms refer only to the distribution of monitoring sites within the sampling network for that pollutant, and "cleaner" or "dirtier" sites may exist in locations where monitoring is not done.

4. Statistical Analysis of Trend

For each of the 11 pollutants, the average concentration trend for the network is determined using those stations with valid averages in each of the two years in question. The network trend is based upon whether the average concentrations at more stations are either increasing or decreasing between the chosen pair of years. A difference between the two annual averages of less than 10% is considered as "No change". The trend is tested to determine whether it was due to random variation or not by the non-parametric Wilcoxon Matched-Pairs, Signed-Ranks Test (See Appendix A). A high confidence level ($\geq 95\%$) indicates the trend was not likely due to random variations. With a confidence level less than 95%, the trend is considered as having "no change". A minimum of 6 stations showing either an increase or decrease (i.e. a difference of 10% or more) is required to apply the test.

The trend analysis used in this report is designed to show changes in the provincial network as a whole. Trends (or the lack of trends) in the network data do not imply that the concentrations for a station or city follow a similar trend. Trends for stations or individual cities are beyond the scope of this study.

It should be noted that the trend analysis can only be applied to those stations which report valid annual means in each of the given years. When the network changes the number of its stations significantly, the possibility arises that the calculated trend may differ from that apparent in the percentile distributions for the two years.

5. Total Suspended Particulate Matter Trends in Ontario

Total suspended particulate matter (TSP) has many sources both natural and man-made. Traditionally, air pollution has been identified by the public as black or dark smoke. Improved combustion technology and a switch to cleaner fuels has eliminated black smoke as a major pollutant. Fine particles of smoke from combustion and dust from construction, mining, metal smelting and processing, grinding processes, and transportation constitute much of man's contribution to TSP. Natural sources include forest fires, wind-blown soil, and volcanoes. The smaller particles are capable of travelling many thousands of kilometers by moving within large masses of air.

Measurement of TSP in Ontario is by the standard high-volume sampling technique. This method collects particles with diameters between 0.1 and 100 micrometers over a 24-hour period. Sampling rates vary in Ontario. Stations sample either daily, once every three days, or once every six days. The annual geometric mean, rather than the arithmetic mean, is used in the trend and distribution analyses.

The box plot of the history of TSP concentrations (Figure 3) shows a substantial decrease in all plotting positions between the years 1973 and 1975. The TSP trend of the median of annual geometric means decreases annually from 1971 to 1978, increases in 1979 and then decreases through 1982. Other plotting levels indicate a general decrease from 1971 to 1975 with a leveling off from 1975 to 1981 at all but the 90 percentile. Trend analysis of annual geometric means indicates that there has been a decrease over the 1971 to 1975 period (Table 3) and that this trend is significant at greater than or equal to a 99% confidence level. For the 1975-79 periods there was no change while the 1979-82 period again shows a decrease significant at the 99% confidence level.

Air quality criteria for TSP are based upon daily and annual means. The percentage of stations meeting the annual criterion of 60 ug/m^3 (geometric mean) is shown in Figure 4a. In 1971, only 11% of the stations met the annual criterion. By 1982, however, 79% were less than the maximum desirable level. The percentage of stations meeting the 24-hour criterion (120 ug/m^3) increased from 4% in 1971 to 23% in 1982 (Figure 4b). Natural sources and long-range transport of particulate matter are significant contributors to measured TSP. Daily levels can, therefore, be significantly influenced by meteorological factors such as precipitation and wind speed, and thus, it is not surprising to see large fluctuations in the number of daily TSP values exceeding the criterion from year to year. During the period of study, for example, the average number of exceedences per station varied from a maximum of 20.1 in 1974 to a minimum of 6.2 in 1982.

6. Soiling Index Trends in Ontario

The soiling index (SI) is a relative measure of suspended particulate matter in the 0.1 to 10 micrometer size range and is based upon the optical transmission density of the particulate matter deposited on the filter. The measure, therefore, is related not only to the amount of particulate matter but also to its physical properties such as opacity. The unit of measure is the Coefficient of Haze (COH) per 1000 feet of air sampled. Data are averaged over one or two hours. The one-hour average SI is connected to the Ontario real-time data acquisition system whereas the two-hour average SI is not. Studies have shown that the two methods are not strictly comparable. Therefore, for the purpose of trend analysis, the one and two hour data are reported separately. The two have been combined, however, when determining criteria exceedences.

The trend of 2-hour soiling index (Figure 5) indicates a distinct decrease over the 1971 to 1979 period for all percentiles amounting to 35% or more. From 1979 to 1982, there was a slight increase. Trend analysis (Table 4) shows significant decrease for the 1971-75 and 1975-79 period and no significant change from 1979 to 1982.

The 1-hour soiling index history (Figure 6) shows variations at all percentiles without definite trend. The network average shows a slight ($\sim 10\%$) decrease from the mid-seventies to the 1980-82 period.

The 24-hour average criterion of 1.0 COH/1000 ft was met at 48-79% of the soiling index monitors (Figure 7a). The percentage of stations meeting the annual average criterion for soiling index of 0.50 COH/1000 ft varied from 87% to 97% between 1971 and 1982 (Figure 7b).

7. Sulphur Dioxide Trends in Ontario

Over one half of Ontario's sulphur dioxide (SO_2) emissions are from the primary smelting of nickel, copper, and iron in the Sudbury and Wawa areas. Thermal generating stations are the largest sources of SO_2 in southern Ontario. The remaining SO_2 is emitted by industrial, commercial, and residential fuel users as well as refineries, coke ovens and other industrial operations. It should be noted, however, that community SO_2 concentrations are, on the long term, affected more by nearby sources often emitting at low elevation than by large and distant sources emitting from tall stacks.

Sulphur dioxide concentrations in Ontario have shown a decrease in the percentiles ranging from 50% to 85% (Figure 8) over the 1971-1982 period. The network trend in annual average concentration (Table 5) decreased significantly at 99% confidence for each of the 3 periods. The largest decreases in the median value came between 1972 and 1973 (30%) and 1973 and 1974 (29%).

The percentages of stations meeting the SO_2 criteria of 0.25 ppm for a 1-hour average, 0.10 ppm for a 24-hour average and 0.02 ppm annual average are shown in Figure 9. In 1971 and 1972 less than one-half of the stations met the annual criterion. Since 1977, over 90% have met that criterion, and in 1982 all met the criterion. The number of stations meeting the 24-hour and 1-hour criterion have also increased (Table 5). The total number of times the criteria were exceeded has dropped despite an increase in the number of monitors. In 1971, 52 monitors exceeded the 24-hour criterion a total of 251 times. In 1982, the exceedences dropped to 14 despite an increase in monitors to 71, a decrease of 94% in the number of exceedences and an improvement of 40% in the number of stations meeting the criterion. The one-hour criterion was exceeded 2018 times in 1971 but only 371 times in 1982, a decrease of 82% despite a 37% increase in the number of stations. There was also a 25% improvement in the number of stations meeting this criterion.

8. Carbon Monoxide Trends in Ontario

In terms of total weight and concentration, carbon monoxide leads all other contaminants in urban air. Mobile sources, trucks and automobiles, are almost exclusively responsible. Although pollution control equipment has reduced the output per car, the increase in the number of vehicles on many streets has limited the overall reduction of carbon monoxide emissions.

The trend in CO in Ontario (Table 6) must be broken into two parts. Prior to 1976, there were less than 10 monitors with sufficient data to calculate an annual average in the Province while from 1976 to 1982 there were 16-21 such monitors in service. The first period plotted with the double-arrow technique (Figure 10) shows a decrease in all levels after 1973. The 1975 average of the annual means for the network was almost half of the 1973 average. From 1976 to 1982, the network average was below the 1975 average concentration remaining constant for the first four years and declining thereafter. Percentiles showed some variability but no definite trend from 1978-1982. The network trend analysis shows that the number of stations was too small to apply the test for the 1971-75 and 1975-79 periods. For the 1979-82 period, 10 stations showed a decrease and 2 an increase. The trend statistics indicate no significant change at the 95% confidence level. The trend was significant downward at the 90% confidence level, however.

Stations meeting the 8-hour criterion of 13 ppm have increased from 65% in 1971 to 96% in 1982 while the total number of exceedences decreased from 30 to 23.

The 1-hour criterion of 30 ppm has been met at almost all sites (Table 6). Most of the exceedences of the 8-hour criteria during the 1977-1982 period occurred at a station located within 4 meters of the street in downtown Toronto.

9. Total Hydrocarbons Trends in Ontario

Hydrocarbon sources include emissions from automobiles and petroleum producing and handling facilities as well as from natural sources such as trees and other vegetation. Two types of measurements are made of hydrocarbons in Ontario. The first uses flame ionization techniques to measure all hydrocarbons and is reported as total hydrocarbons. Methane, however, does not participate in a number of photochemical reactions which form oxidants. Thus, measurements have also been made with the methane fraction removed, and the resulting hydrocarbon measurement is referred to as reactive hydrocarbons. Reactive hydrocarbon measurements began at a few selected sites in 1976, and not enough data exists for determination of trends.

No criteria have yet been established for reactive or total hydrocarbons as effects will depend upon the concentration of the specific hydrocarbon species.

Since the number of total hydrocarbon monitors has varied around 10 for the 1971-1982 period, the trend history (Figure 11) has utilized the double-arrow method only. The average of the annual means shows no definite trend oscillating between 2.12 and 1.87 ppm.

10. Ozone Trends in Ontario

Ozone is a naturally occurring constituent of the upper atmosphere. In the lower atmosphere, it is generally a secondary product of photochemical reactions among reactive hydrocarbons and nitrogen oxides. In the upper atmosphere, ozone plays an important role in the maintenance of life on the ground by absorbing harmful ultra-violet radiation. In the lower atmosphere, however, ozone is detrimental to the health of man and plants as well as enhancing damage to various materials.

Since time is needed for these photochemical reactions to be completed, ozone is often found some distance from the source of its pollutant precursors. Thus, high concentrations of ozone which occur at rural location are not indicative of natural or local sources but reflect the transport and reaction in the presence of adequate sunlight of the ozone precursors from the upwind urban sources.

In 1973, a monitoring instrument using chemiluminescence methods to measure ozone specifically became available. During 1974, there was a change in the Ontario monitoring network from oxidants to ozone. Therefore, the trend analysis begins with the year 1974. There is a large variation in year-to-year concentrations (Figure 12) but no definite trend.

Since ozone formation is very dependent upon weather conditions, as is the transport of ozone formed from precursors emitted at distance, differences from year to year will reflect weather variations as well as changes in precursor emissions. Ozone is also seasonally dependent with highest concentrations occurring during the spring and summer.

Exceedences of the 1-hour ozone criterion of 80 ppb are frequent, their annual total being dependent also on weather conditions. Only in 1974 did the number of stations meeting the criterion exceed 20% (Table 8). This figure is somewhat misleading since many of the stations were installed after the summer season when hourly concentrations are at their peak.

11. Nitrogen Oxides Trends in Ontario

The oxides of nitrogen (NO and NO_2) are generated by natural as well as anthropogenic sources. Nitrogen and oxygen, which are the principal constituents of the atmosphere, combine during high temperature combustion to form nitrogen oxides. The main sources are automobile exhausts, power plants, incinerators and chemical processes. Lightning and soil bacteria are the main source of natural nitrogen oxides in the lower atmosphere.

No evidence exists that nitric oxide (NO) at the concentrations measured in the atmosphere has any direct adverse effect on health and welfare. Oxidation of nitric oxide to nitrogen dioxide (NO_2), however, does occur, and nitrogen dioxide is known to affect health as well as visibility. The nitrogen oxides also play an important role in the photochemical reactions involving ozone and other oxidants. Nitrogen oxides have also been implicated in the acidification of precipitation.

Although there has been some form of measurements of nitrogen oxides since 1971, the trend analyses commence with the 1974 data when monitoring by chemiluminescence techniques was begun. Data taken earlier with other methods are not strictly comparable with present analysis techniques.

There is a general downward trend in average NO_2 concentrations over the 1974 to 1982 period (Figure 13). Most stations meet the daily NO_2 criterion of 0.10 ppm and the hourly criterion of 0.20 ppm (Table 9).

The nitric oxide monitoring network was established in 1974 and doubled in size in the 1976-1982 period. There is a decreasing trend in the 90 percentile and, the network average, but no apparent trend for other plotting positions (Table 10, Figure 14). No criteria have been set for NO as there are no known adverse effects at concentrations which occur in the atmosphere.

Nitrogen oxides (NO_x) essentially the sum of NO and NO_2 , show a downward trend at all plotting for the period 1977 to 1982 (Figure 15, Table 11).

12. Total Reduced Sulphur Trends in Ontario

The first extensive monitoring of total reduced sulphur (TRS) began in Ontario in 1976. Most of the total reduced sulphur compounds may be found in the form of hydrogen sulphide. In the vicinity of pulp and paper mills and refineries, however, significant concentrations of mercaptans and other reduced sulphurs may be present.

From the double-arrow plots (Figure 16, Table 12) there is no apparent trend in the network average until 1982 when a substantial drop occurred due to a decrease in the concentration at the station reporting the maximum concentration from 12.2 to 5.5 ppb, the result of abatement measures at the nearby source.

13. Particulate Lead Trends in Ontario

Much of the particulate lead found in the atmosphere has been released in the combustion of gasoline containing lead additives. Other sources of lead include the secondary smelting of lead, battery manufacture, metal fabrication (brass, bronze, and solder), some paint and glass manufacture, and the production of iron, steel, copper and nickel. Since 1972, there has been a reduction in the lead content of leaded gasoline and in 1975, unleaded gasoline was introduced; the effect of these two actions has reduced the 1982 emission of lead from automobiles by 59% as compared to 1971 levels.

Lead concentrations showed a slight rise from 1971 to 1974 followed by a significant decline from 1974 to 1982 (Figure 17). These changes follow closely the total amount of lead consumed in Ontario due to gasoline usage (Table 13). The average lead concentration of all stations (except those surrounding lead-processing plants) and the consumption of lead through gasoline usage were nearly perfectly correlated with a correlation coefficient of 0.97.

The criterion for lead is 5.0 ug/m^3 for a 24-hour concentration. The percentage of stations meeting this criterion on all monitoring days has been between 70% and 95% for all years except 1973-1975 (Figure 17) - the peak years of lead emissions from gasoline usage. The total number of occasions that the criterion was exceeded has decreased 82% since 1974 despite an increase in the number of monitors from 27 in 1971 to 71 in 1982. Much of this reduction can be attributed to controls imposed on emissions from lead processing plants.

14. Ontario's Air Pollution Index

An Air Pollution Index (API) based upon the 24-hour average concentration of sulphur dioxide and suspended particulate matter has been in use in Ontario since March 1970. Air Pollution Index stations were established in Toronto and Hamilton in 1970, Sudbury and Windsor in 1971, Welland and Niagara Falls in 1974, Coniston in 1975, New Sudbury in 1976, Sarnia in 1977, and St. Catharines in 1979. The station installed in Happy Valley in 1971 was discontinued in 1975, and the Welland station was shut-down in 1978. The API at all stations have a common base; an API of 32 is

defined as having SO₂ and soiling index levels equal to the desirable air quality criteria for sulphur dioxide and soiling index on a 24-hour average. When the API exceeds 57, health effects may increase in incidence, especially for the elderly and those with respiratory problems.

At an API of 32 with adverse weather conditions expected for the next 6 hours, suspected offending industries are alerted and may be asked to cut-back on their operations. At an API of 50 with adverse conditions expected for 6 hours, the Minister may order curtailment of industrial operations, and a shut-down may be ordered by the Minister if the Index exceeds 100.

The history of the Index stations, the maximum level and the number of periods during which the Index equalled or exceeded 32 and 50 for the years 1971 to 1982, is given in Table 14.

While the API is designed as a control measure to be utilized when adverse weather conditions cause prolonged elevated concentrations of particulate matter and SO₂ and is, therefore, very dependent upon weather and climatic fluctuations, the influence of source emission control is also evident, especially in the cities of Toronto, Sudbury and Windsor. Except for 1979 when unusual weather conditions prevailed, Hamilton has also shown a significant reduction in the number of occasions when the API exceeded 32.

15. Summary

Air quality in Ontario has shown a significant improvement over the years 1971 to 1982 for total suspended particulate matter, particulate lead, soiling index, sulphur dioxide and carbon monoxide. Much of this reduction can be attributed to emission source regulation during the mid-1970's. In the past few years, pollutant concentrations have fluctuated in response to changes in weather and climate as much as to changes in emissions.

The network average for total suspended particulate matter decreased 48% over the 1971-1982 period. Decreases of 31% for 2-hour soiling index and 68% for carbon monoxide were also found for this period as was a decrease in particulate lead of 45%. Sulphur dioxide concentrations were reduced by 68% in the 1972 to 1982 period.

Decreases of 22%, 49%, and 41% were found for nitrogen dioxide, nitric oxide and nitrogen oxides, respectively, for the 1976 to 1982 period.

The number and percentage of stations meeting the Ontario criteria for desirable air quality has increased over the period of study. In addition, the total number of exceedences of short term criteria has decreased for many pollutants despite an increase in the number of monitoring stations.

The Ontario monitoring network has grown and been modified over the 1971-1982 period in response to the needs for air quality surveillance across the province. There has also been, and continues to be, an increase in the number of chemical species monitored.

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TABLE 1

ONTARIO AIR QUALITY MONITORING NETWORK 1971 TO 1982

Number of Monitoring Locations Across Ontario

<u>Year</u>	<u>Pollutant</u>							
	<u>TSP</u>	<u>Lead</u>	<u>SO₂</u>	<u>Soil</u>	<u>O_x</u>	<u>O₃</u>	<u>CO</u>	<u>TRS</u>
1971	88	85	52	54	11	0	17	0
1972	105	27	49	57	8	0	19	0
1973	109	45	47	49	9	2	11	1
1974	129	55	51	52	7	13	13	2
1975	143	78	55	59	0	16	15	9
1976	142	89	67	64	0	19	18	10
1977	146	72	72	65	0	25	20	11
1978	155	92	80	69	0	28	22	12
1979	159	75	81	60	0	31	21	12
1980	182	84	80	63	0	33	24	16
1981	175	71	70	54	0	36	24	19
1982	163	80	69	53	0	33	23	23

(Table continued on next page)

(Table 1. continued)

<u>Year</u>	<u>NO₂</u>	<u>NO</u>	<u>NO_x</u>	<u>THC</u>	<u>RHC</u>	<u>CH₄</u>	<u>Total*</u>
1971	0	0	16	16	0	0	254
1972	12	0	17	16	0	0	283
1973	20	0	6	16	0	0	269
1974	18	4	9	18	0	0	314
1975	22	13	18	17	0	0	367
1976	20	18	19	18	4	0	389
1977	23	20	21	17	4	0	424
1978	25	21	23	16	4	0	455
1979	25	24	24	13	7	2	459
1980	30	27	30	13	9	3	510
1981	25	25	25	12	10	6	481
1982	27	27	27	11	9	4	469

Legend: TSP - total suspended particulate matter; Lead - lead in suspended particulate matter; SO₂ - sulphur dioxide;

Soil - soiling index; O_x - oxidants; O₃ - ozone; THC - total hydrocarbons; RHC - reactive (non-methane) hydrocarbons; CH₄ - methane;

CO - carbon monoxide; NO₂ - nitrogen dioxide; NO - nitric oxide; NO_x - nitrogen oxides;

TRS - total reduced sulphur (expressed as hydrogen sulphide).

* Lead stations not included in total.

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TABLE 2

Desirable Ambient Air Quality Criteria in Ontario
(abstracted from Ontario Regulation 872/74)

Name of Contaminant	Unit of Measurement	Average Amount or Concentration	Period of Time
Carbon Monoxide	parts of carbon monoxide per one million parts of air by volume	30	1 hr.
		13	8 hr.
Nitrogen Dioxide	parts of nitrogen dioxide per one million parts of air by volume	0.20	1 hr.
		0.10	24 hr.
Ozone	parts of ozone per one billion parts of air by volume	80	1 hr.
Soiling Index	Coefficient of Haze per 1000 feet of air	1.0	24 hr.
		0.5	1 yr.
Sulphur Dioxide	parts of sulphur dioxide per one million parts of air by volume	0.25	1 hr.
		0.10	24 hr.
		0.02	1 yr.
Total Suspended Particulate Matter	micrograms of suspended particulate matter per cubic meter of air	120	24 hr.
		60 (geom. mean)	1 yr.
Lead in Suspended Particulate Matter	micrograms of particulate lead per cubic meter of air	5.0	24 hr.

TABLE 3

Total Suspended Particulate Matter in Ontario 1971-1982
(Unit: micrograms per cubic meter - $\mu\text{g}/\text{m}^3$)

Year	No. of Stations*	Network Average of Geometric Means	Percentiles					% Meeting Annual Criterion	Total No. of Stations	% Meeting 24-hour Criterion	Total Exceedences 24-hour Criterion
			10	25	50	75	90				
1971	54	95	59	69	85	118	136	11	88	4	1350
1972	71	96	52	68	83	113	148	16	105	13	1559
1973	69	90	56	67	82	104	137	17	109	8	1848
1974	96	76	43	58	71	88	106	28	129	14	2590
1975	99	65	37	50	65	76	89	41	143	15	1845
1976	109	64	39	47	62	76	90	47	142	13	2177
1977	115	61	37	46	57	70	103	57	146	17	1592
1978	121	59	37	42	55	71	106	57	155	16	1821
1979	129	65	38	48	64	76	94	44	159	15	2138
1980	126	63	41	50	62	73	88	47	182	30	1830
1981	139	53	34	40	50	62	75	69	175	22	1371
1982	143	49	34	38	46	57	67	79	166	23	1025

Trend Analysis of Annual Geometric Means

Period	Increasing	Number of Stations*		No Change	Network Trend	Confidence Level
		Decreasing				
1971-1975	0	47		2	Down	99%
1975-1979	29	21		44	No Change	< 95%
1979-1982	2	92		30	Down	99%

*Stations with sufficient number of samples to meet the following criteria for determining valid annual geometric mean: more than 20 samples per year with at least 4 samples per season.

TABLE 4

Soiling Index in Ontario 1971-1982

(Unit: COH/1000 ft.)

Year	2-Hour Sampling Rate							1-Hour Sampling Rate						
	No. of Stations*	Network	Percentiles					No. of Stations*	Network	Percentiles				
		Average	10	25	50	75	90		Average	10	25	50	75	90
1971	27	.32	.23	.25	.29	.36	.43	4	.52	(.26	minimum)		(.67	maximum
1972	26	.33	.20	.25	.29	.35	.47	11	.32	.11	.13	.32	.37	.43
1973	25	.30	.17	.20	.24	.38	.44	10	.31	(.08	minimum)		(.48	maximum
1974	29	.30	.18	.22	.29	.33	.42	11	.38	.06	.07	.30	.46	.54
1975	24	.25	.15	.17	.23	.29	.36	12	.38	.14	.15	.31	.43	.44
1976	31	.24	.13	.18	.23	.28	.31	16	.37	.12	.26	.38	.47	.49
1977	36	.23	.16	.19	.21	.25	.31	16	.37	.10	.14	.34	.48	.54
1978	35	.21	.13	.16	.19	.24	.28	17	.39	.13	.24	.40	.44	.56
1979	25	.18	.11	.15	.16	.20	.28	19	.37	.12	.19	.32	.47	.61
1980	29	.19	.13	.17	.20	.22	.24	21	.32	.14	.18	.31	.42	.52
1981	30	.22	.16	.18	.23	.26	.30	20	.33	.15	.19	.31	.43	.60
1982	28	.22	.14	.15	.22	.27	.32	22	.34	.17	.18	.32	.46	.53

Year	Number of Stations*	% Meeting Annual Criterion	Total Number of Stations	% Meeting 24-hr Criterion	Total Exceedences of 24-hr Criterion
1971	31	87	54	37	258
1972	37	92	57	54	198
1973	35	97	49	51	235
1974	40	92	52	50	241
1975	36	97	59	63	141
1976	47	96	64	59	178
1977	52	90	65	66	201
1978	52	90	69	68	208
1979	44	91	60	60	263
1980	51	94	63	79	164
1981	50	92	54	56	211
1982	50	94	52	48	225

Trend Analysis of Annual Means

Period	Number of 2-hour Stations*			Network Trend	Confidence Level	Number of 1-hour Stations*			Network Trend	Confidence Level
	Increasing	Decreasing	No Change			Increasing	Decreasing	No Change		
1971-1975	1	13	4	Down	99%	0	4	1	No Change	TNA
1975-1979	1	6	7	Down	95%	2	4	3	No Change	<95%
1979-1982	6	7	8	No Change	<95%	2	5	10	No Change	<95%

TNA - Test Not Applicable

*Stations with sufficient number of samples (6570 for 1-hr; 3285 for 2-hr) to determine valid annual mean.

TABLE 5
Sulphur Dioxide in Ontario 1971-1982
(Unit: parts per million-ppm)

Year	No. of Stations*	Network Average	Percentiles					% Meeting Annual Criterion	Total No. of Stations	% Meeting 24-hour Criterion	Total Exceedences 24-hour Criterion	% Meeting 1-Hour Criterion	Total Exceedences 1-hour Criterion
			10	25	50	75	90						
1971	8	.038	(.015 minimum)			(.065 maximum)		12	52	52	251	31	2018
1972	13	.025	.013	.015	.020	.025	.030	46	49	61	144	37	1286
1973	22	.015	.003	.008	.014	.017	.021	77	47	74	70	47	687
1974	34	.014	.003	.006	.010	.017	.022	82	51	69	98	37	1154
1975	39	.012	.004	.007	.011	.015	.020	87	55	71	63	45	864
1976	48	.013	.005	.008	.011	.016	.020	85	67	78	86	51	1140
1977	54	.011	.004	.006	.011	.015	.017	93	72	78	67	62	1015
1978	59	.009	.003	.005	.008	.012	.015	100	80	84	80	61	912
1979	59	.008	.002	.004	.007	.011	.015	98	81	83	38	57	635
1980	58	.008	.003	.004	.007	.012	.014	98	81	84	74	60	936
1981	62	.009	.003	.004	.007	.010	.014	97	70	89	61	63	780
1982	57	.006	.003	.004	.005	.008	.011	100	71	92	14	56	371

Trend Analysis of Annual Means

Period	Number of Stations*			Network Trend	Confidence Level
	Increasing	Decreasing	No Change		
1971-1975	0	6	1	Down	99%
1975-1979	1	22	6	Down	99%
1979-1982	1	30	9	Down	99%

*Stations with sufficient number of samples (6570) to determine valid annual mean.

TABLE 6
Carbon Monoxide in Ontario 1971-1982
(Unit: parts per million - ppm)

Year	No. of Stations*	Network Average	Percentiles					Total No. of Stations	8-hour Criterion		1-hour Criterion	
			10	25	50	75	90		% Stations Meeting	Total Exceedences	% Stations Meeting	Total Exceedences
1971	6	3.7	(2.4	minimum)	(6.0	maximum)		17	65	30	100	0
1972	2	4.4	(4.0	minimum)	(4.8	maximum)		19	84	34	95	5
1973	5	4.2	(2.2	minimum)	(8.6	maximum)		10	80	24	85	2
1974	6	2.8	(1.9	minimum)	(5.2	maximum)		13	85	6	100	0
1975	8	2.2	(0.9	minimum)	(4.8	maximum)		15	93	3	100	0
1976	16	1.6	0.7	1.0	1.4	1.8	1.9	18	100	0	100	0
1977	16	1.6	0.7	1.1	1.5	1.8	2.2	20	95	12	95	2
1978	18	1.6	0.3	0.9	1.5	1.9	2.2	22	91	48	95	50
1979	21	1.6	0.3	0.9	1.3	1.6	2.0	21	86	57	95	28
1980	22	1.4	0.1	0.6	1.3	1.7	2.2	24	96	39	96	20
1981	20	1.4	0.2	1.0	1.3	2.0	2.4	24	96	17	92	41
1982	23	1.2	0.1	0.4	1.1	1.6	1.9	23	96	23	96	4

Trend Analysis of Annual Means

Period	Number of Stations*			Network Trend	Confidence Level
	Increasing	Decreasing	No Change		
1971-1975	0	4	0	No Change	Test Not Applicable
1975-1979	0	4	2	No Change	Test Not Applicable
1979-1982	2	10	8	No Significant Change	< 95%

*Stations with sufficient number of samples (6570) to determine valid annual mean.

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TABLE 7

Total Hydrocarbons in Ontario 1971-1979

(Unit: parts per million - ppm)

<u>Year</u>	<u>No. of Stations*</u>	<u>Network Average</u>	<u>Network Minimum</u>	<u>Percentiles</u>					<u>Network Maximum</u>
				<u>10</u>	<u>25</u>	<u>50</u>	<u>75</u>	<u>90</u>	
1971	5	2.10	1.73	-	-	-	-	-	2.54
1972	8	2.02	1.59	-	-	-	-	-	2.31
1973	12	2.00	1.59	1.59	1.75	1.92	2.12	2.15	2.78
1974	9	2.03	1.82	-	-	-	-	-	2.80
1975	11	2.01	1.65	1.65	1.80	1.87	2.19	2.21	2.29
1976	14	2.09	1.55	1.55	1.67	2.11	2.32	2.39	2.57
1977	11	1.93	1.23	1.23	1.60	1.87	2.17	2.22	2.35
1978	7	2.06	1.48	-	-	-	-	-	2.56
1979	9	1.92	1.32	-	-	-	-	-	2.30
1980	9	1.87	1.43	-	-	-	-	-	2.41
1981	9	2.08	1.68	-	-	-	-	-	2.36
1982	10	2.12	1.66	-	-	-	-	-	2.48

Trend Analysis of Annual Means

<u>Period</u>	<u>Number of Stations*</u>			<u>Network Trend</u>	<u>Confidence Level</u>
	<u>Increasing</u>	<u>Decreasing</u>	<u>No Change</u>		
1971-1975	0	1	2	No Change	Test Not Applicable
1975-1979	1	3	3	No Change	Test Not Applicable
1979-1982	3	0	5	No Change	Test Not Applicable

*Stations with sufficient number of samples (6570) to determine valid annual mean.

TABLE 8
Ozone in Ontario 1974-1982
(Unit: parts per billion - ppb)

<u>Year</u>	<u>No. of Stations*</u>	<u>Network Average</u>	<u>Percentiles</u>					<u>Total No. of Stations</u>	<u>Total % Meeting 1-hour Criterion</u>	<u>Exceedences 1-hour Criterion</u>
			<u>10</u>	<u>25</u>	<u>50</u>	<u>75</u>	<u>90</u>			
1974	5	19.7	(13.7	minimum)		(31.0	maximum)	13	23	826
1975	12	23.1	16.4	18.2	22.3	24.3	24.4	16	6	2747
1976	15	18.8	12.0	15.3	17.4	20.5	22.9	19	0	1849
1977	18	20.8	11.3	16.6	19.5	22.1	26.5	25	16	1906
1978	21	22.3	12.7	17.3	19.2	27.6	29.3	28	7	3716
1979	23	18.7	11.0	14.4	17.2	23.2	25.9	31	6	1540
1980	25	18.9	12.1	15.4	18.5	22.8	24.8	33	9	1994
1981	27	18.9	13.3	15.2	18.8	23.4	28.9	36	11	1552
1982	30	19.5	12.2	14.8	17.8	22.7	26.6	32	6	743

Trend Analysis of Annual Means

<u>Period</u>	<u>Number of Stations*</u>			<u>Network Trend</u>	<u>Confidence Level</u>
	<u>Increasing</u>	<u>Decreasing</u>	<u>No Change</u>		
1976-1979	1	4	5	No Change	Test Not Applicable
1979-1982	3	2	19	No Change	Test Not Applicable

*Stations with sufficient number of samples (6570) to determine valid annual mean.

TABLE 9
Nitrogen Dioxide in Ontario 1974-1982
(Unit: parts per million - ppm)

Year	No. of Stations*	Network Average	Percentiles					Total No. of Stations	24-Hour Criterion		1-Hour Criterion	
			10	25	50	75	90		% Stations Meeting	Total Exceedences	% Stations Meeting	Total Exceedences
1974	4	.032	(.026	minimum)		(.044		6	83	5	83	13
1975	6	.029	(.021	minimum)		(.044		16	88	3	69	19
1976	14	.027	.008	.017	.027	.032	.038	19	100	0	100	0
1977	16	.031	.013	.020	.028	.039	.042	22	82	10	91	13
1978	18	.028	.012	.018	.031	.035	.038	24	88	5	92	2
1979	22	.024	.010	.013	.026	.030	.034	25	96	1	96	1
1980	21	.022	.011	.018	.022	.028	.030	30	100	0	97	1
1981	21	.021	.011	.017	.022	.029	.030	25	95	1	88	16
1982	25	.021	.007	.015	.021	.027	.032	27	96	1	96	1

Trend Analysis of Annual Means

Period	Number of Stations*			Network Trend	Confidence Level
	Increasing	Decreasing	No Change		
1976-1979	4	5	4	No Change	< 95%
1979-1982	2	6	12	Down	95%

*Stations with sufficient number of samples (6570) to determine valid annual mean.

TABLE 10
Nitric Oxide in Ontario 1975-1982
(Unit: parts per million - ppm)

<u>Year</u>	<u>No. of Stations</u>	<u>Network Average</u>	<u>Percentiles</u>				
			<u>10</u>	<u>25</u>	<u>50</u>	<u>75</u>	<u>90</u>
1975	2	.122	(.033	minimum)		(.211	maximum)
1976	11	.045	.001	.010	.025	.033	.076
1977	13	.048	.010	.017	.026	.032	.078
1978	15	.043	.005	.008	.027	.049	.069
1979	20	.030	.003	.017	.021	.034	.059
1980	22	.024	.005	.009	.019	.029	.062
1981	21	.028	.006	.014	.020	.037	.061
1982	26	.023	.002	.008	.017	.029	.052

Trend Analysis of Annual Means

<u>Period</u>	<u>Number of Stations*</u>			<u>Network Trend</u>	<u>Confidence Level</u>
	<u>Increasing</u>	<u>Decreasing</u>	<u>No Change</u>		
1976-1979	3	6	2	No Change	<95%
1979-1982	0	11	5	Down	99%

*Stations with sufficient number of samples (6570) to determine valid annual mean.

TABLE 11
Nitrogen Oxides in Ontario 1974-1982
(Unit: parts per million - ppm)

<u>Year</u>	<u>No. of Stations*</u>	<u>Network Average</u>	<u>Percentile</u>				
			<u>10</u>	<u>25</u>	<u>50</u>	<u>75</u>	<u>90</u>
1974	4	.117	(.055	minimum)		(.263	maximum)
1975	8	.094	(.048	minimum)		(.254	maximum)
1976	13	.075	.039	.052	.065	.107	.135
1977	14	.080	.033	.048	.065	.117	.153
1978	15	.071	.019	.037	.068	.099	.133
1979	20	.054	.013	.021	.049	.079	.101
1980	22	.045	.013	.030	.044	.059	.093
1981	21	.046	.013	.030	.041	.055	.087
1982	20	.044	.008	.014	.038	.054	.076

Trend Analysis of Annual Means

<u>Period</u>	<u>Number of Stations*</u>			<u>Network Trend</u>	<u>Confidence Level</u>
	<u>Increasing</u>	<u>Decreasing</u>	<u>No Change</u>		
1976-1979	2	7	3	No Change	<95%
1979-1982	0	11	7	Down	99%

*Stations with sufficient number of samples (6570) to determine valid annual mean.

TABLE 12
Total Reduced Sulphur in Ontario 1975-1982
(Unit: parts per billion - ppb)

<u>Year</u>	<u>No. of Stations*</u>	<u>Network Average</u>	<u>Network Minimum</u>	<u>Network Maximum</u>
1975	3	1.0	0.0	1.9
1976	5	3.4	0.6	12.8
1977	8	3.2	0.0	15.4
1978	8	4.2	0.0	16.1
1979	6	3.6	0.5	10.2
1980	10	4.1	0.3	11.5
1981	15	3.1	0.2	12.2
1982	17	1.7	0.1	5.5

Trend Analysis of Annual Means

<u>Period</u>	<u>Increasing</u>	<u>Number of Stations*</u>		<u>Network Trend</u>	<u>Confidence Level</u>
		<u>Decreasing</u>	<u>No Change</u>		
1975-1979	1	0	0	No Change	Test Not Applicable
1979-1982	3	6	0	No Change	< 95%

*Stations with sufficient number of samples (6570) to determine valid annual mean.

TABLE 13

Lead in Suspended Particulate Matter in Ontario 1971-1982

(Unit: micrograms per cubic meter - $\mu\text{g}/\text{m}^3$)

Year	No. of Stations*	Network Average	Percentile					Total No. of Stations	% Stations Meeting 24-hour Criterion	Total Exceedences 24-hour Criterion	Lead Consumed in Gasoline-10 ² -g
			10	25	50	75	90				
1971	27	1.0	0.3	0.5	0.8	1.0	1.3	85	85	43	5.49
1972	20	1.8	0.3	0.6	0.8	1.3	3.7	27	81	60	6.10
1973	26	1.4	0.4	0.6	0.8	1.4	1.8	45	64	174	6.40
1974	38	1.4	0.2	0.5	1.0	1.5	2.6	55	53	529	5.93
1975	33	1.2	0.2	0.5	0.9	1.4	2.1	78	72	428	5.18
1976	35	1.3	0.3	0.4	0.8	1.4	2.0	89	85	529	4.98
1977	41	0.9	0.2	0.3	0.5	1.2	1.5	72	79	436	4.35
1978	66	0.6	0.1	0.3	0.4	0.7	1.1	92	87	360	3.81
1979	53	0.5	0.1	0.2	0.3	0.6	1.0	75	85	342	3.23
1980	61	0.4	0.1	0.2	0.3	0.5	0.7	84	89	242	2.99
1981	71	0.4	0.1	0.2	0.2	0.5	0.7	71	90	146	2.97
1982	71	0.3	0.1	0.2	0.2	0.3	0.4	80	95	94	2.24

Trend Analysis

Period	Number of Stations*			Network Trend	Confidence Level
	Increasing	Decreasing	No Change		
1971-1975	0	5	0	No Change	Test Not Applicable
1975-1979	0	27	1	Down	99%
1979-1982	0	39	16	Down	99%

*Stations with sufficient number of samples to meet the following criteria for determining valid annual mean: more than 20 samples per year with at least 4 samples per season.

**of geometric means

ONTARIO'S AIR POLLUTION INDEX

Date Started:	TORONTO	MARCH	23,	1970
	HAMILTON	JUNE	15,	1970
	SUDBURY	JANUARY	16,	1971
	WINDSOR	MARCH	19,	1971
	HAPPY VALLEY	MAY	13,	1971 (Closed Jan. 1975)
	WELLAND	JANUARY	1,	1974 (Closed Oct. 1978)
	NIAGARA FALLS	NOVEMBER	1,	1974
	CONISTON	FEBRUARY	18,	1975
	NEW SUDBURY	MARCH	1,	1976
	SARNIA	DECEMBER	1,	1977
	ST. CATHARINES	SEPTEMBER	14,	1979

<u>YEAR</u>	<u>CITY</u>	<u>NUMBER OF</u>		<u>MAXIMUM</u>	<u>DATE OF</u>
		<u>≥ 32</u>	<u>≥ 50</u>		
				<u>INDEX</u>	<u>MAXIMUM</u>
1970	TORONTO	17	2	56	Oct. 8
	HAMILTON	2	1	56	Oct. 8
1971	TORONTO	19	1	52	Apr. 13
	HAMILTON	23	NIL	48	Oct. 21
	SUDBURY	26	3	87	Dec. 11
	WINDSOR	2	NIL	33	Nov. 10
	HAPPY VALLEY	20	7	64	Nov. 21
1972	TORONTO	2	NIL	45	Feb. 13
	HAMILTON	6	NIL	41	Feb. 13
	SUDBURY	7	1	79	June 12
	WINDSOR	9	1	53	Jan. 29
	HAPPY VALLEY	20	11	139	Mar. 23
1973	TORONTO	3	NIL	43	Oct. 24
	HAMILTON	2	NIL	34	Feb. 14
	SUDBURY	NIL	NIL	26	Mar. 14
	HAPPY VALLEY	19	10	94	Aug. 21
	WINDSOR	7	NIL	44	Feb. 19
1974	TORONTO	3	1	50	Oct. 29
	HAMILTON	11	NIL	44	Oct. 29
	SUDBURY	1	NIL	32	July 13
	WINDSOR	2	NIL	41	Jan. 7
	HAPPY VALLEY	24	13	116	Apr. 23
	NIAGARA FALLS	NIL	NIL	20	Nov. 9
	WELLAND	46	15	77	Oct. 6
1975	TORONTO	2	1	62	Nov. 20
	HAMILTON	10	NIL	38	Oct. 24
	SUDBURY	NIL	NIL	30	Feb. 1
	WINDSOR	NIL	NIL	28	Feb. 11
	WELLAND	NIL	NIL	23	Jan. 24
	NIAGARA FALLS	NIL	NIL	21	Nov. 24
	CONISTON	NIL	NIL	30	May 13

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ONTARIO'S AIR POLLUTION INDEX

<u>YEAR</u>	<u>CITY</u>	<u>NUMBER OF</u> <u>OCCASIONS</u>		<u>MAXIMUM</u>	<u>DATE OF</u>
		<u>≥ 32</u>	<u>≥ 50</u>	<u>INDEX</u>	<u>MAXIMUM</u>
1976	TORONTO	1	NIL	33	Oct. 3
	HAMILTON	8	NIL	41	Dec. 16
	SUDBURY	NIL	NIL	28	June 6
	WINDSOR	1	NIL	34	Dec. 16
	WELLAND	NIL	NIL	24	Dec. 16
	NIAGARA FALLS	NIL	NIL	25	Feb. 21
	CONISTON	NIL	NIL	29	Sept. 16
	NEW SUDBURY	NIL	NIL	29	Apr. 2,3 & June 20
1977	TORONTO	4	NIL	36	Jan. 15
	HAMILTON	10	NIL	44	Mar. 12
	SUDBURY	NIL	NIL	24	June. 11
	WINDSOR (12008)	1	NIL	33	Apr. 19
	WELLAND	NIL	NIL	22	Jan. 24,25
	CONISTON	NIL	NIL	25	Apr. 25
	WINDSOR (12016)	NIL	NIL	29	Apr. 19
	NEW SUDBURY	1	NIL	39	June 11
	SARNIA	NIL	NIL	15	Dec. 13
	NIAGARA FALLS	NIL	NIL	28	Feb. 21
1978	TORONTO	2	NIL	45	Nov. 5
	HAMILTON	7	NIL	43	Nov. 4
	SUDBURY	NIL	NIL	31	Jan. 22
	WINDSOR (12008)	1	NIL	33	Apr. 19
	WELLAND	NIL	NIL	24	Mar. 15
	NIAGARA FALLS	NIL	NIL	23	Nov. 4, Mar. 11
	CONISTON	3	NIL	34	Feb. 7
	WINDSOR (12016)	NIL	NIL	28	Feb. 18
	NEW SUDBURY	1	NIL	42	Feb. 2
	SARNIA	3	NIL	41	Jan. 24
1979	TORONTO	2	NIL	35	Oct. 18
	HAMILTON	23	1	55	Dec. 22
	SUDBURY	NIL	NIL	18	July 7
	WINDSOR (12008)	NIL	NIL	31	Feb. 20
	NIAGARA FALLS	NIL	NIL	27	Feb. 21
	CONISTON	NIL	NIL	31	Feb. 14
	NEW SUDBURY	NIL	NIL	28	Feb. 14
	SARNIA	2	NIL	43	Feb. 20
	ST. CATHARINES	NIL	NIL	29	Nov. 6
	WINDSOR (12016)	NIL	NIL	27	Feb. 21
1980	TORONTO	NIL	NIL	31	Dec. 8
	HAMILTON	5	NIL	40	Oct. 16
	SUDBURY	NIL	NIL	23	Oct. 16
	WINDSOR (12008)	NIL	NIL	25	Feb. 8,9
	WINDSOR (12016)	NIL	NIL	25	Dec. 29
	NIAGARA FALLS	NIL	NIL	18	May 24
	CONISTON	NIL	NIL	30	Feb. 10, Mar. 9
	NEW SUDBURY	NIL	NIL	24	July 3, Oct. 16
	SARNIA	1	NIL	39	Mar. 20
	St. CATHARINES	NIL	NIL	28	Feb. 20

ONTARIO'S AIR POLLUTION INDEX

<u>YEAR</u>	<u>CITY</u>	<u>NUMBER OF</u> <u>OCCASIONS</u>		<u>MAXIMUM</u> <u>INDEX</u>	<u>DATE OF</u> <u>MAXIMUM</u>
		<u>≥ 32</u>	<u>≥ 50</u>		
1981	TORONTO	3	NIL	43	Nov. 14
	HAMILTON	8	NIL	38	Nov. 15
	SUDBURY	NIL	NIL	21	Jan. 31
	WINDSOR (12008)	1	NIL	42	Nov. 17
	WINDSOR (12016)	NIL	NIL	31	Nov. 17
	NIAGARA FALLS	NIL	NIL	25	Jan. 14
	CONISTON	NIL	NIL	20	Nov. 25
	NEW SUDBURY	NIL	NIL	22	Jan. 28-29
	SARNIA	1	NIL	34	Feb. 16
	ST. CATHARINES	NIL	NIL	27	Jan. 14-15
1982	TORONTO	3	2	54	Oct. 27
	HAMILTON	12	NIL	39	Dec. 2
	SUDBURY	NIL	NIL	15	Feb. 3
	WINDSOR (12008)	NIL	NIL	31	Oct. 26-27
	WINDSOR (12016)	1	NIL	35	Oct. 27
	NIAGARA FALLS	NIL	NIL	19	Jan. 19
	CONISTON	1	NIL	39	Feb. 5
	NEW SUDBURY	NIL	NIL	29	Feb. 5
	SARNIA	NIL	NIL	27	Mar.11, Nov. 7-8.
	ST. CATHARINES	NIL	NIL	31	Nov. 18

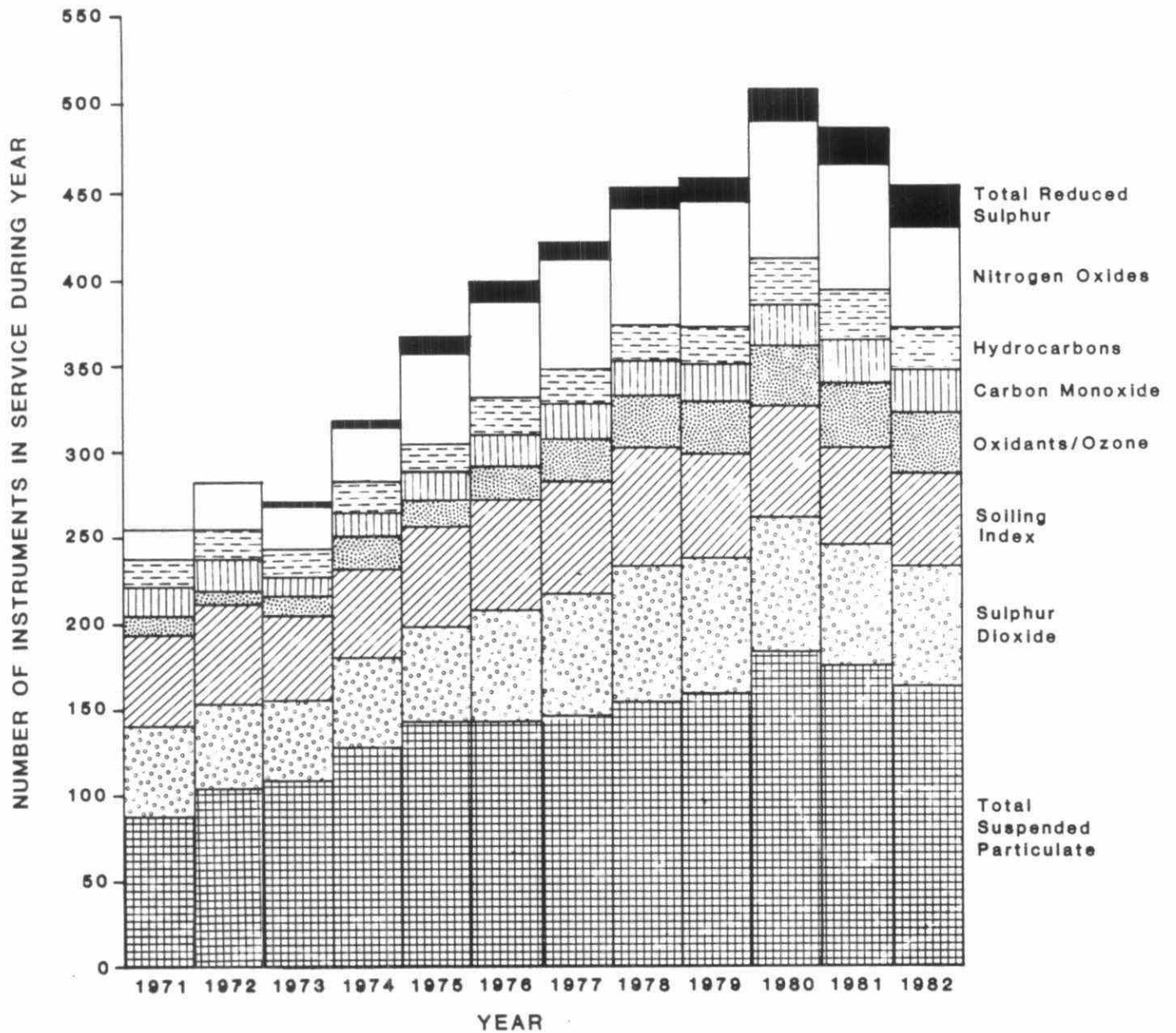
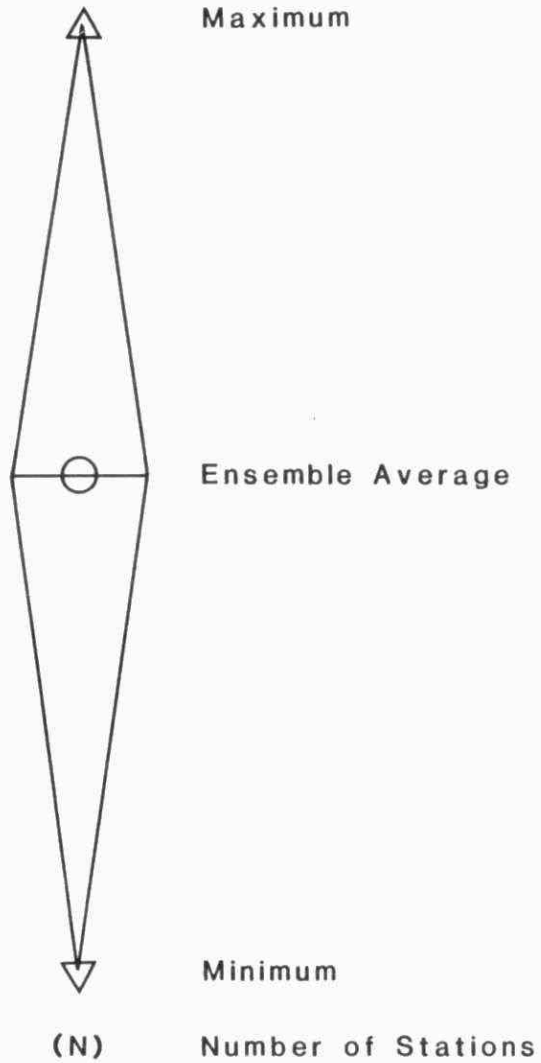


Figure 1 : Ontario Air Quality Monitoring Network 1971-1982

a) Double Arrow Plot



b) Box Plot

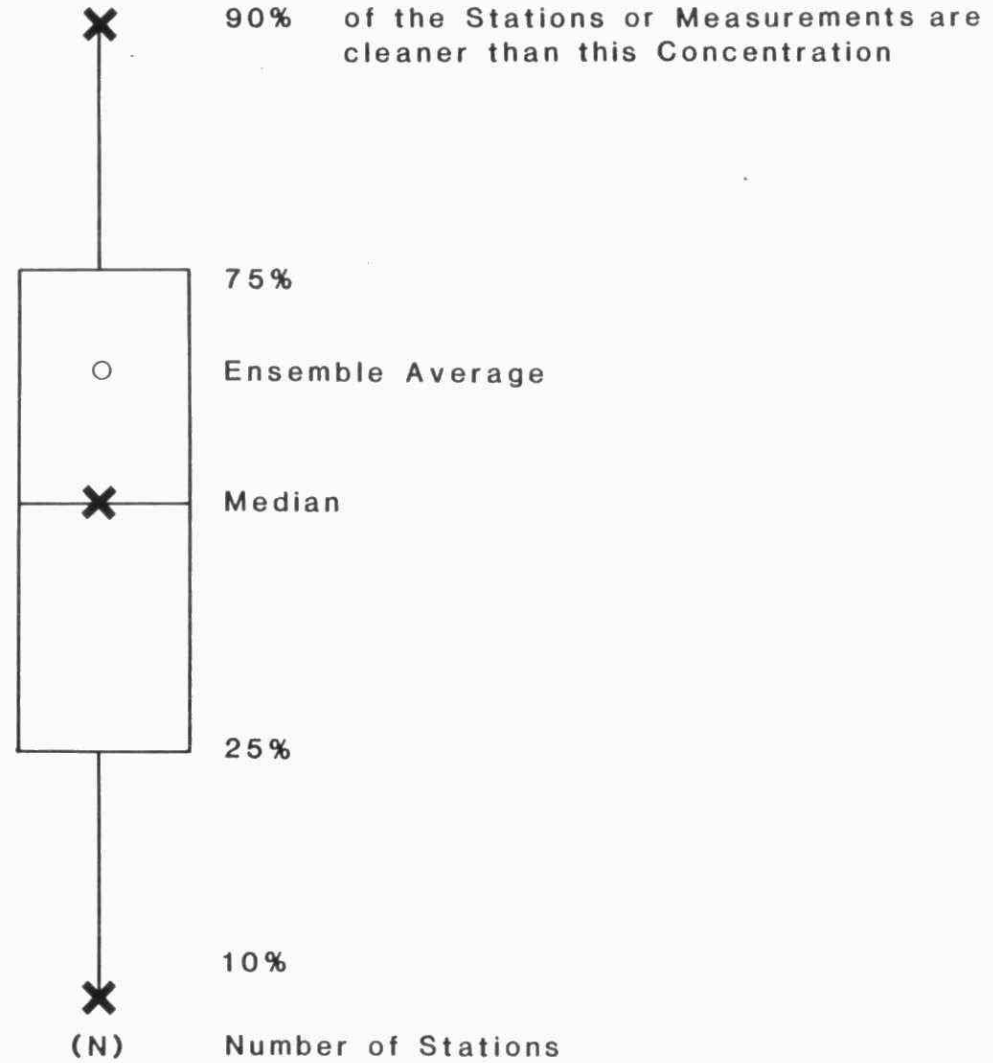


Figure 2 : Plotting Conventions

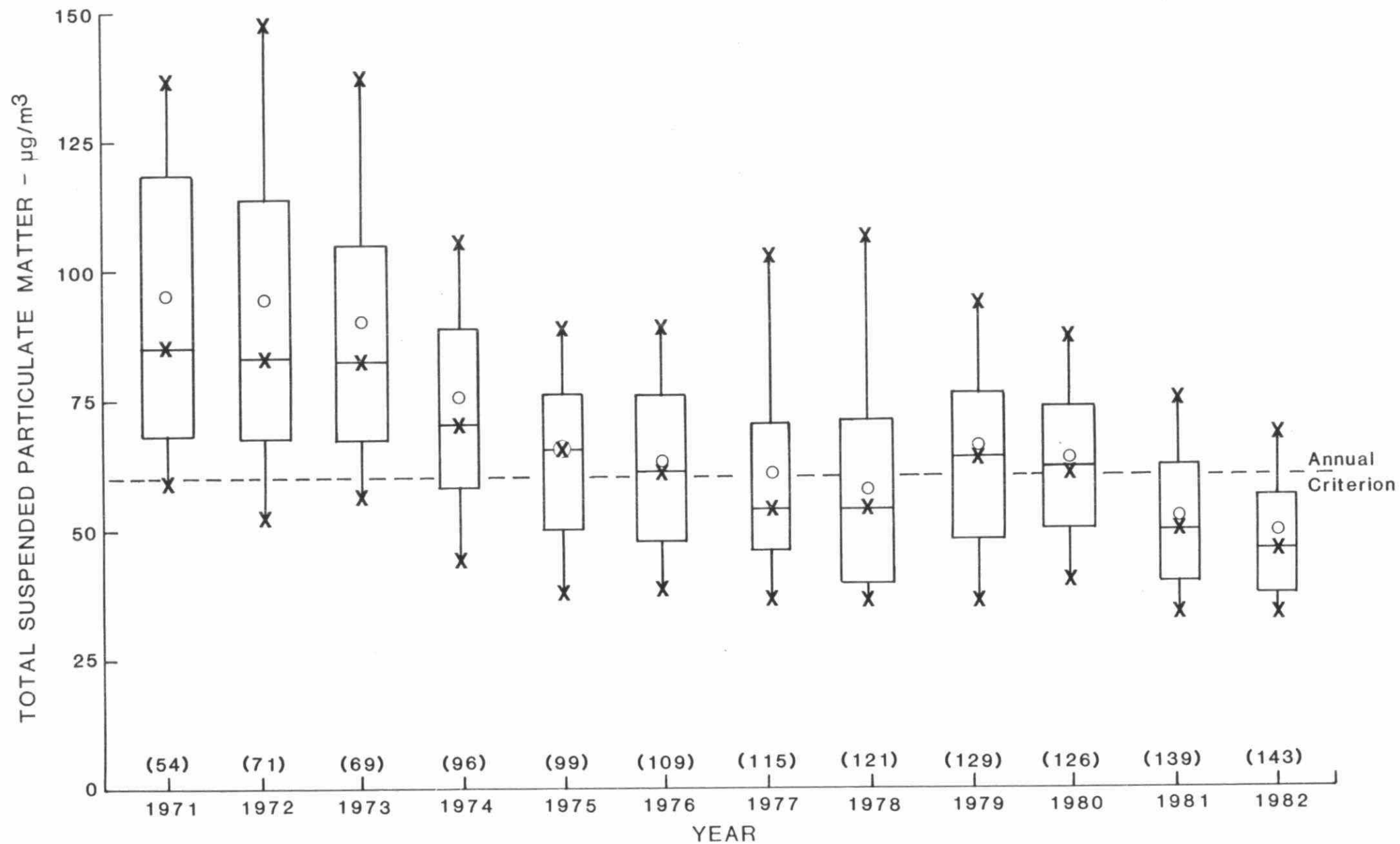


Figure 3 : Trend of Total Suspended Particulate Matter in Ontario 1971-1982

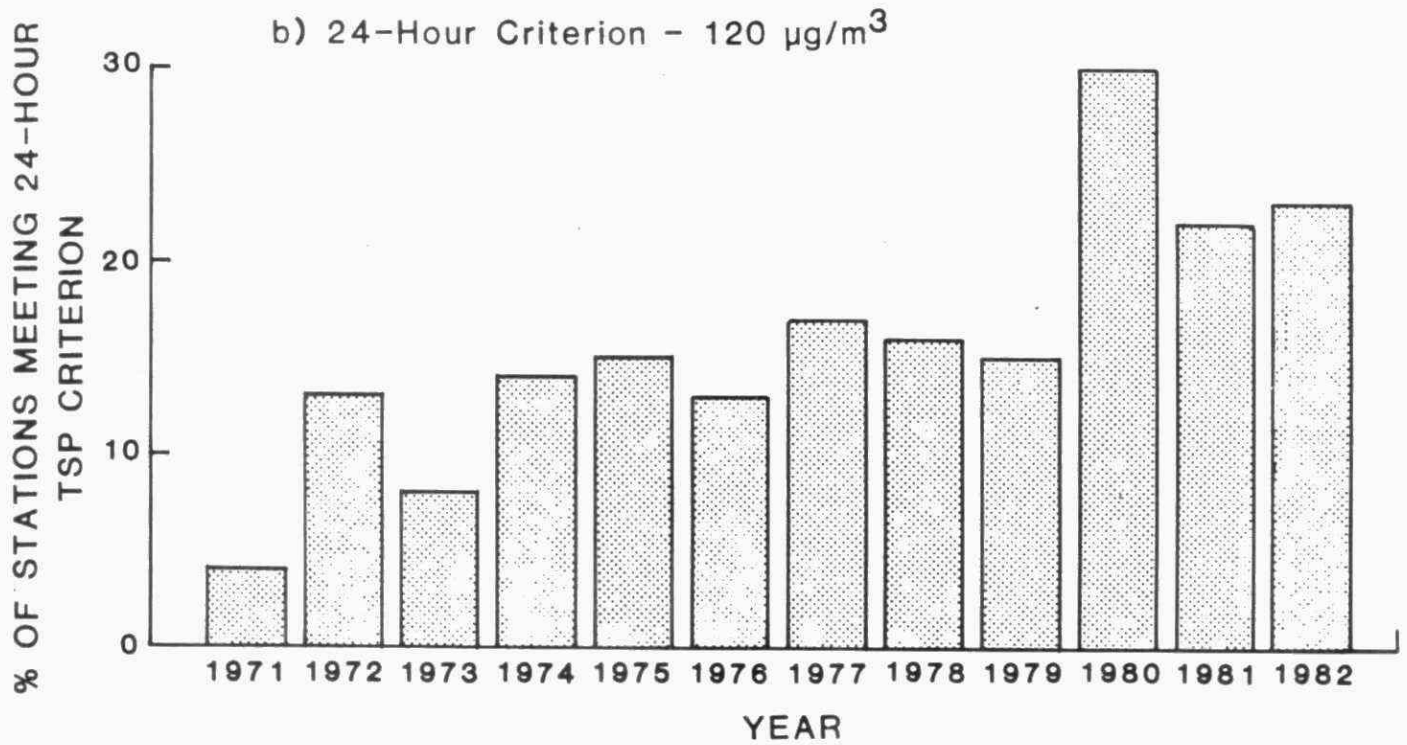
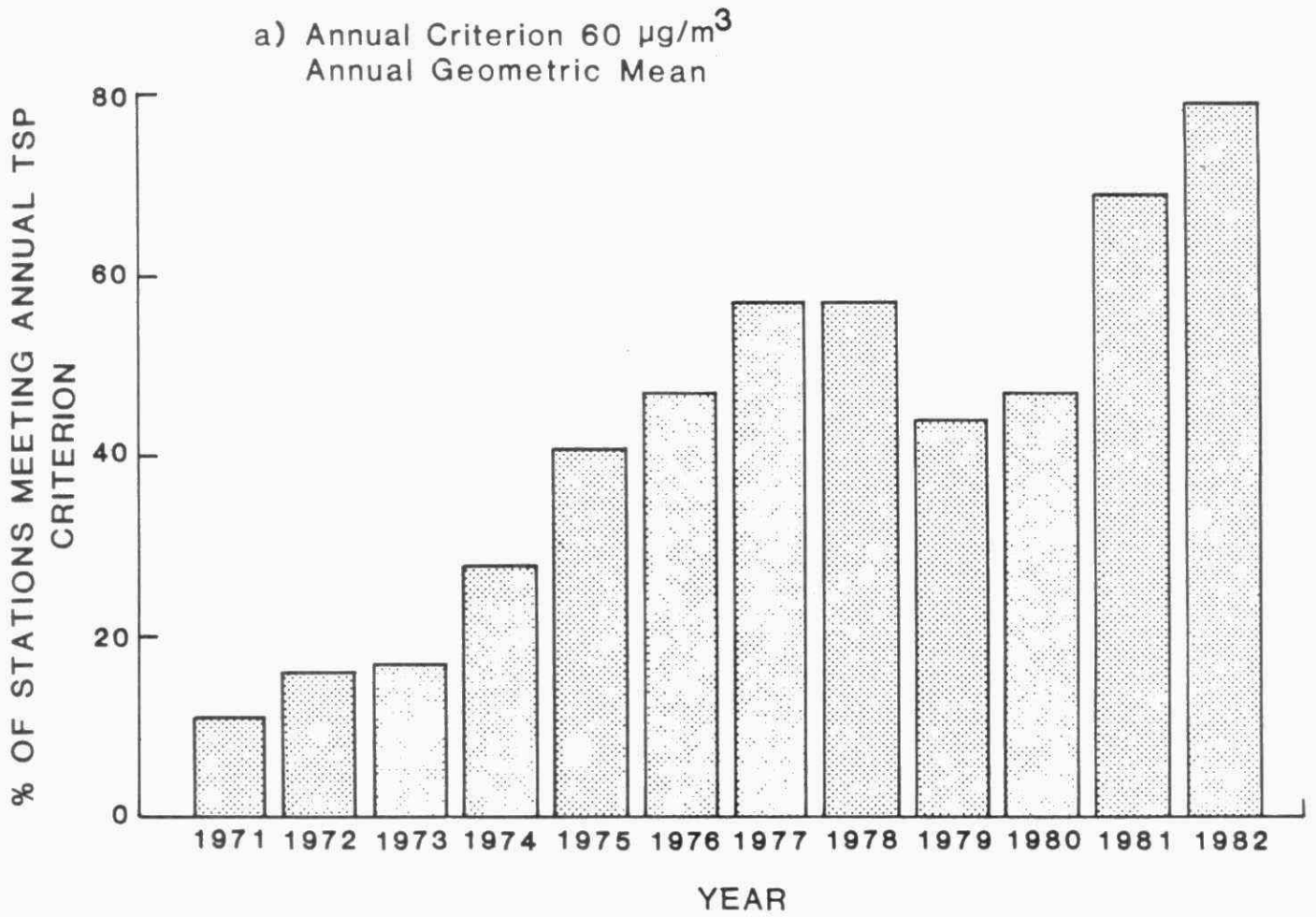


Figure 4 : Percentage of Stations Meeting Criteria for Total Suspended Particulate Matter 1971-1982

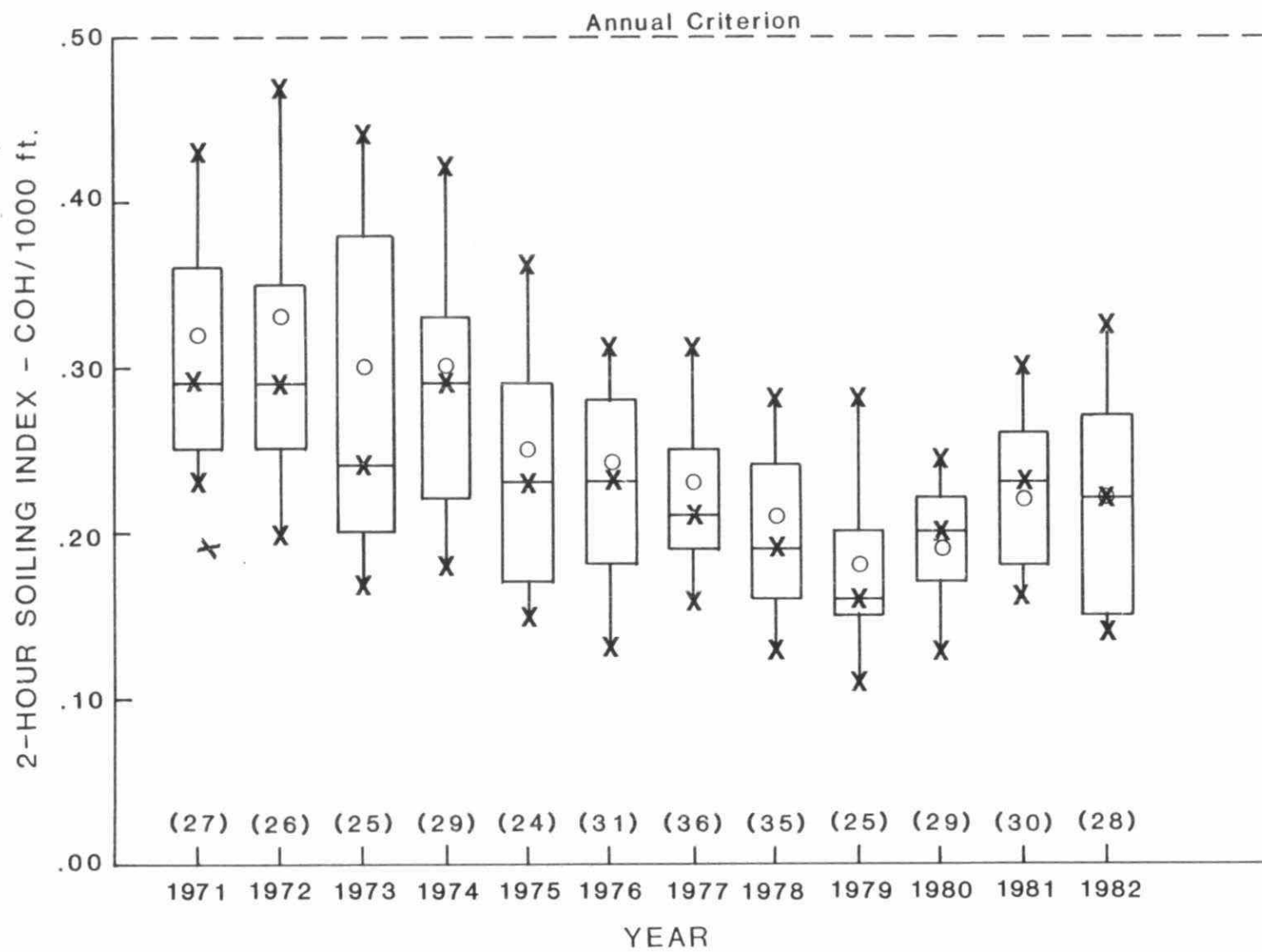


Figure 5 : Trend of 2-Hour Soiling Index in Ontario 1971-1982

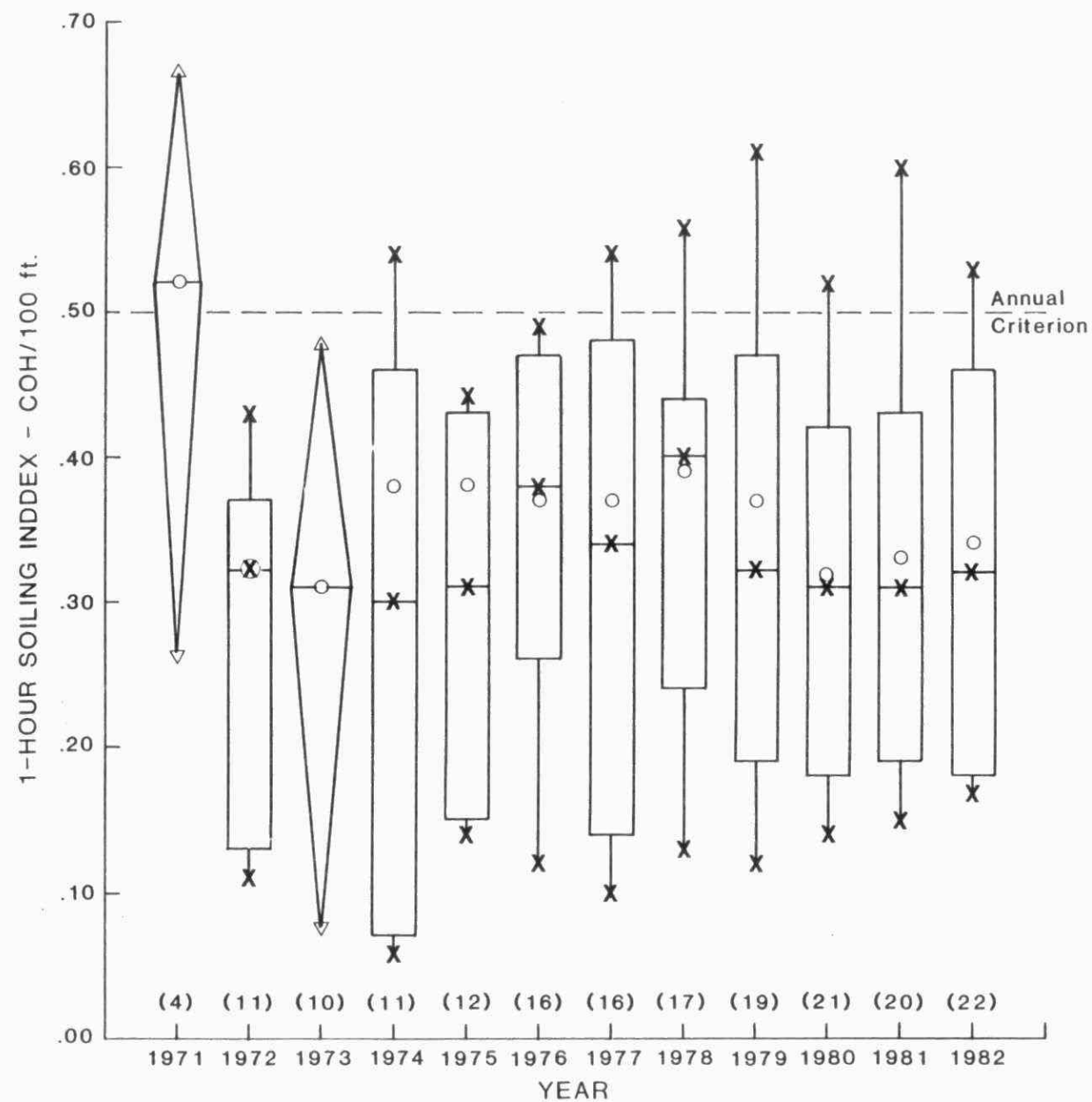


Figure 6 : Trend of 1-Hour Soiling Index in Ontario 1971-1982

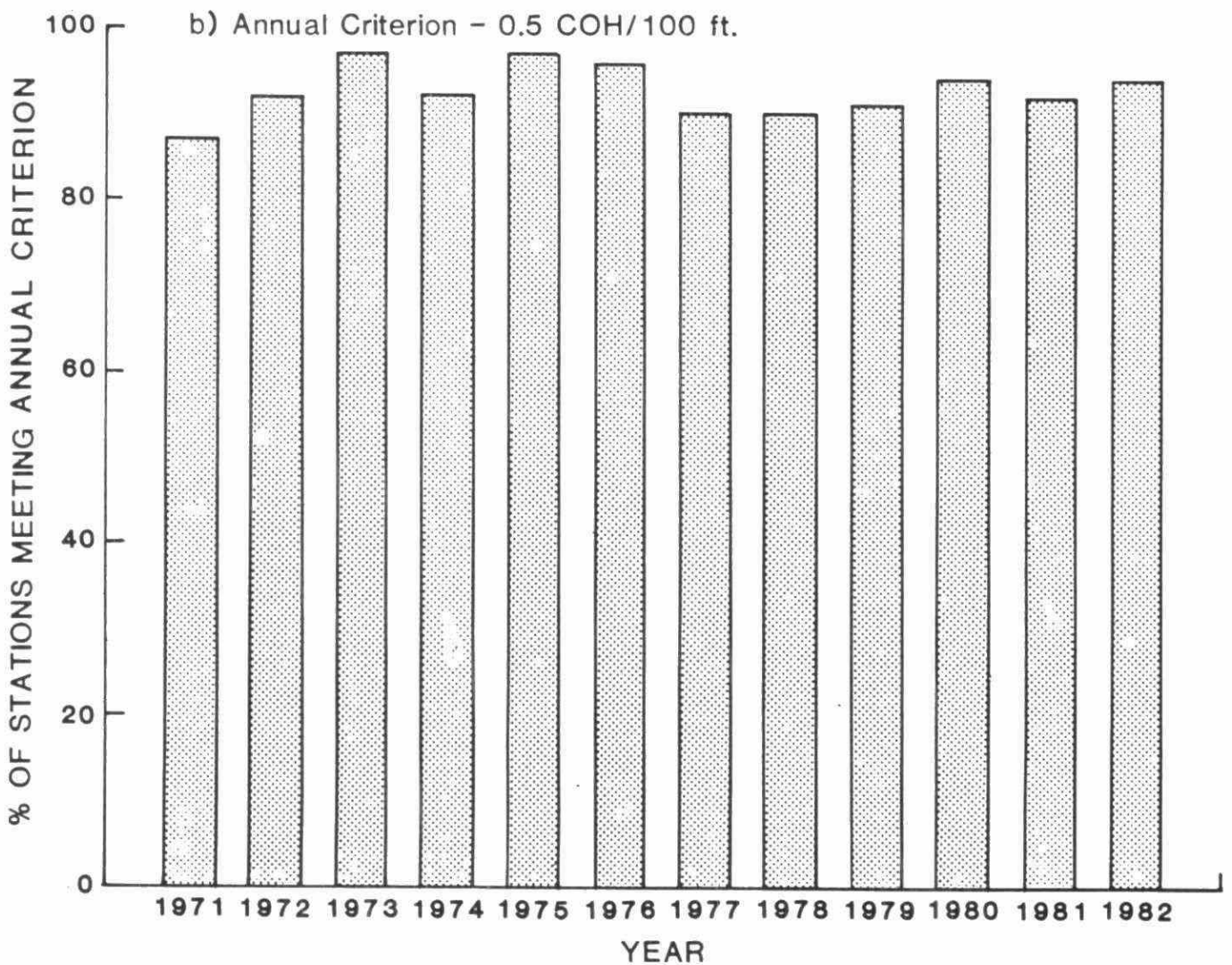
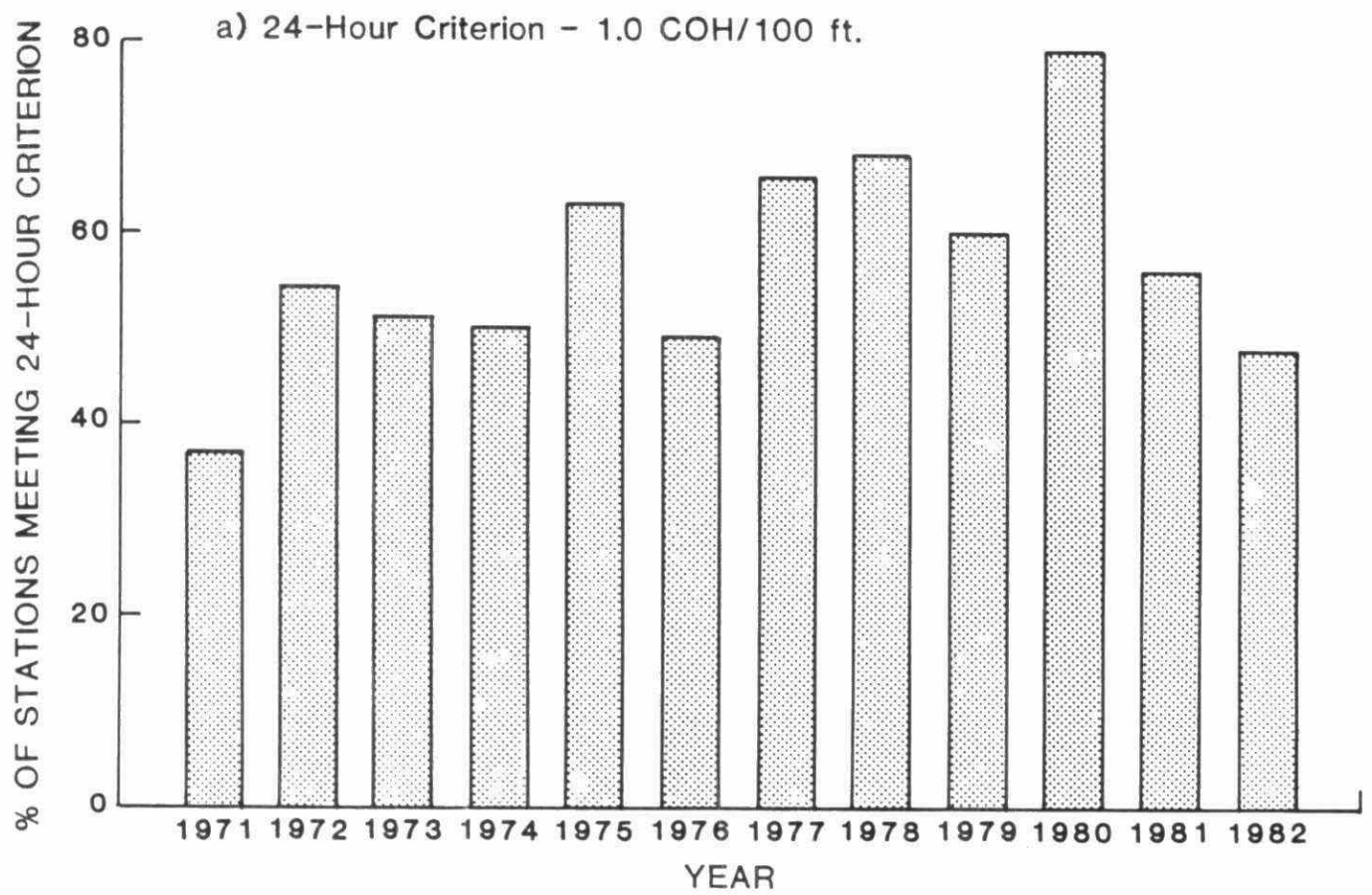


Figure 7 : Percentage of Stations Meeting Soiling Index Criteria
1971-1982

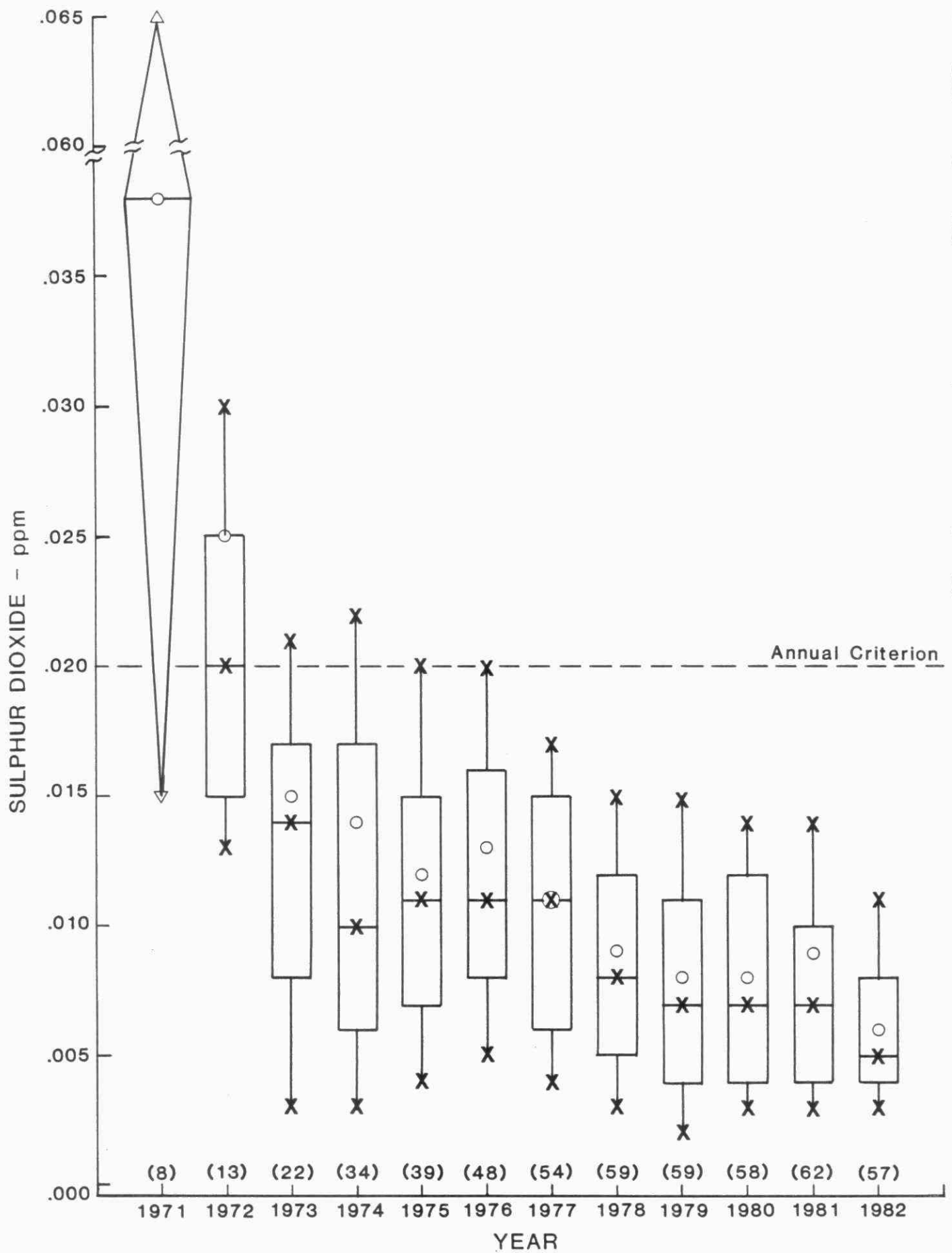


Figure 8 : Trend of Sulphur Dioxide in Ontario 1971-1982

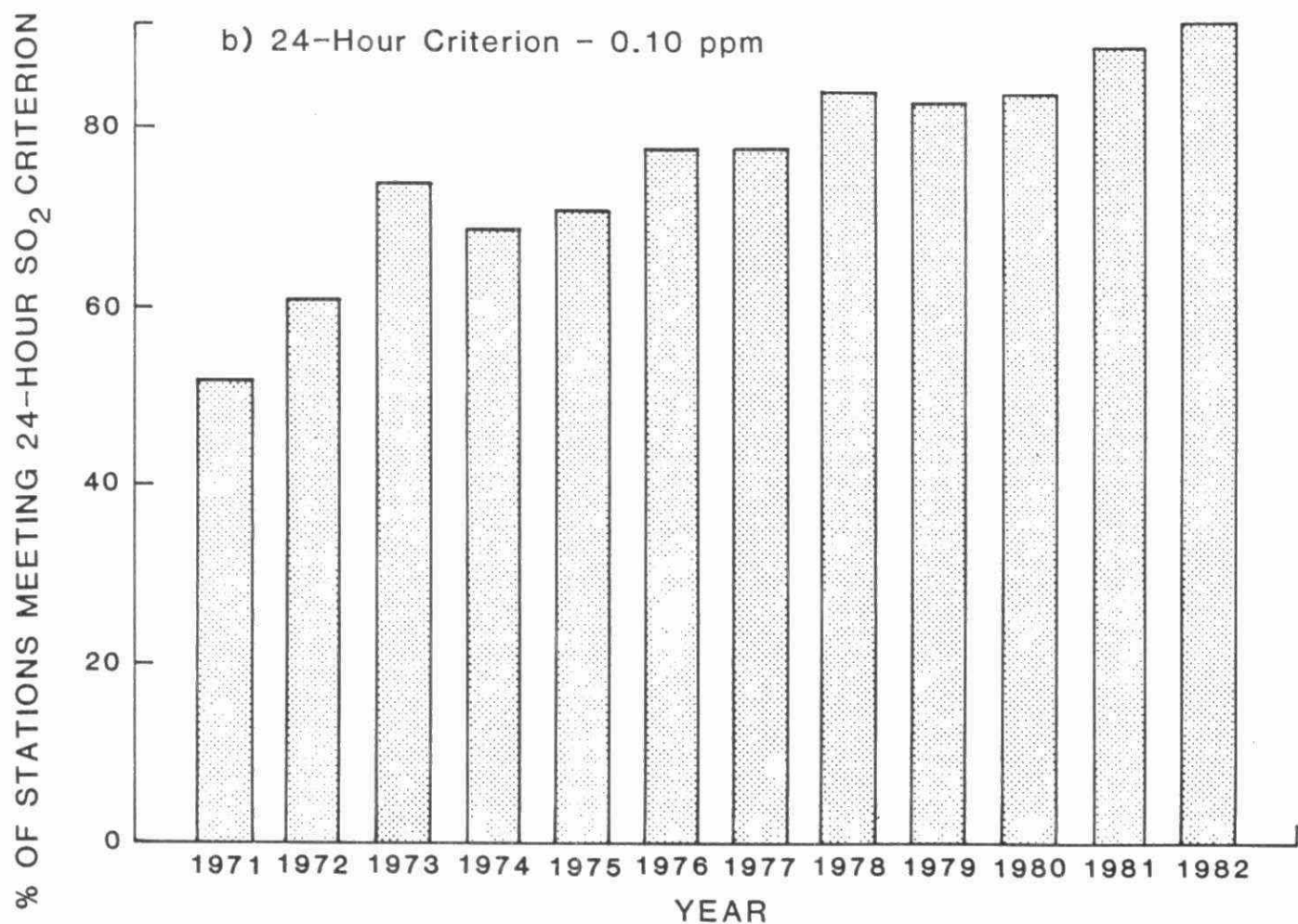
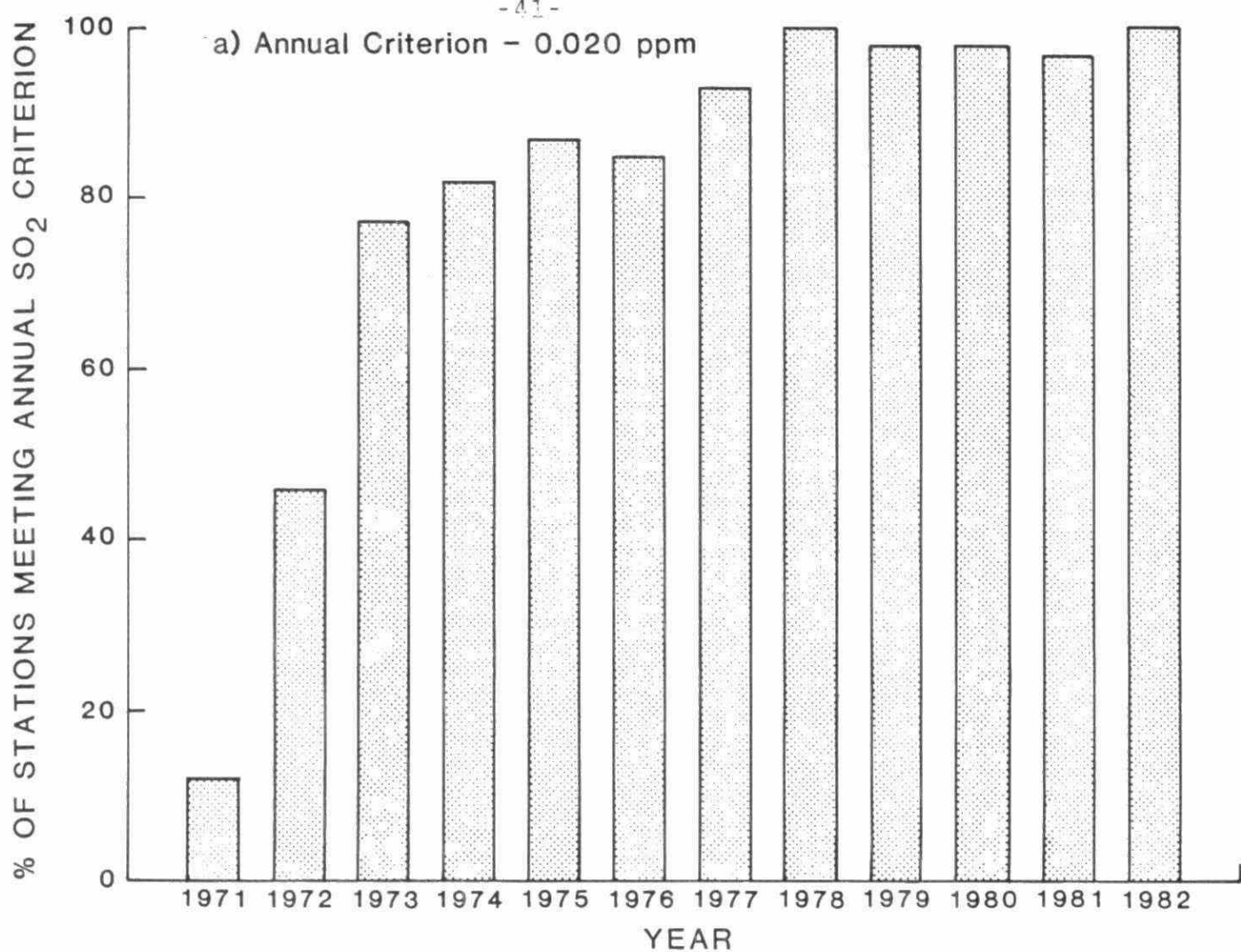


Figure 9 : Percentage of Stations Meeting Sulphur Dioxide Criteria
1971-1982

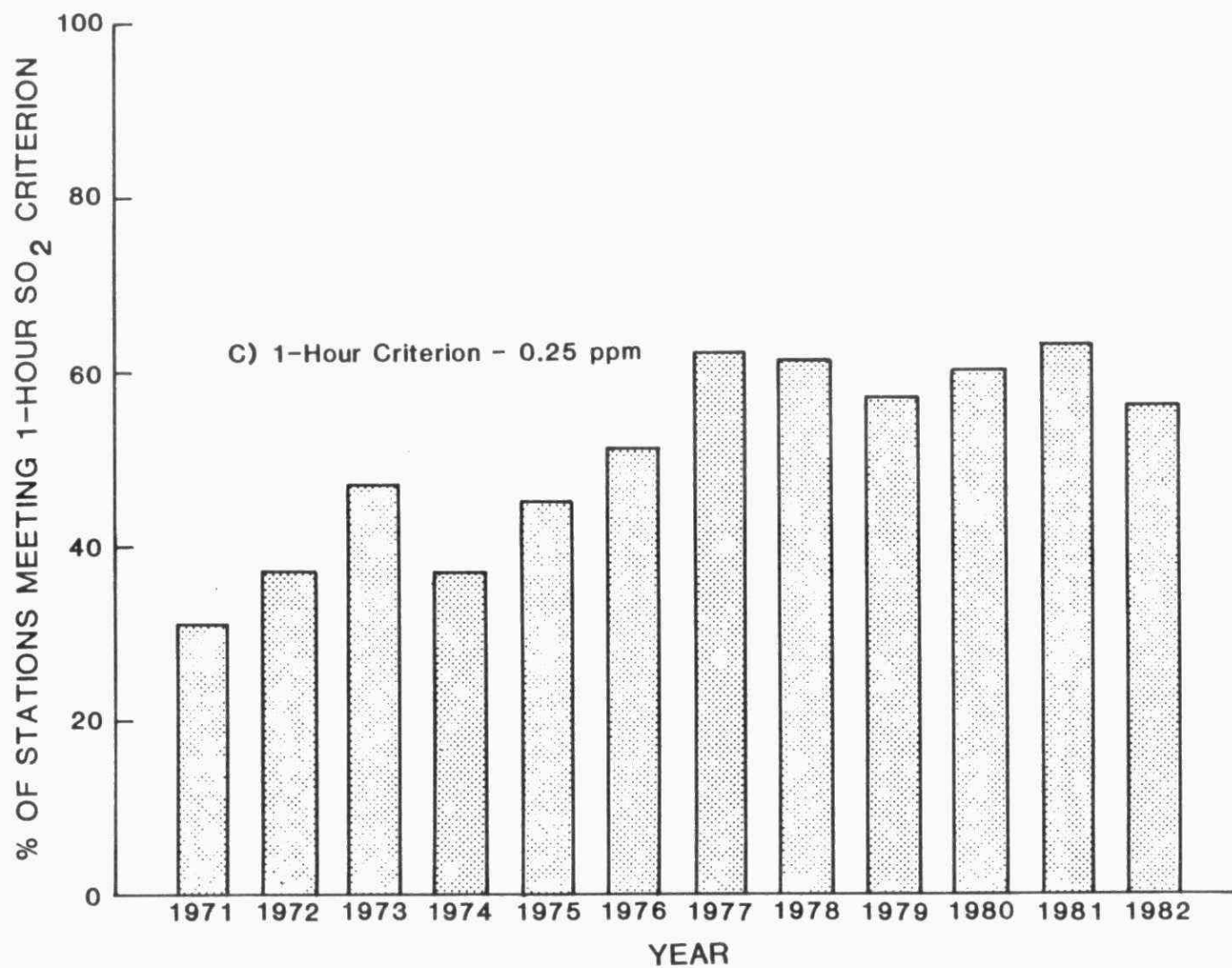


Figure 9 : Percentage of Stations Meeting Sulphur Dioxide Criteria 1971-1982

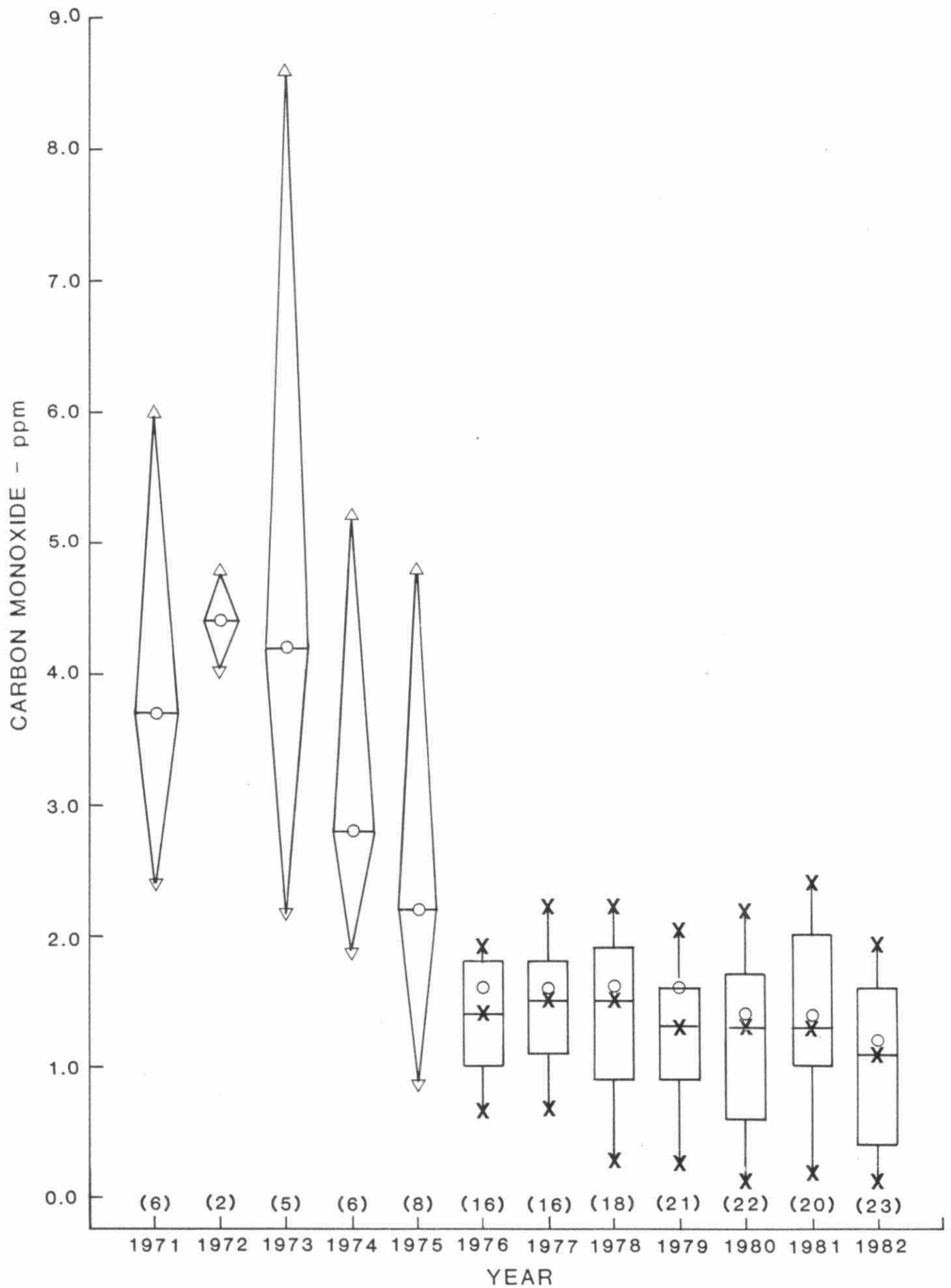


Figure 10 : Trend of Carbon Monoxide in Ontario 1971-1982

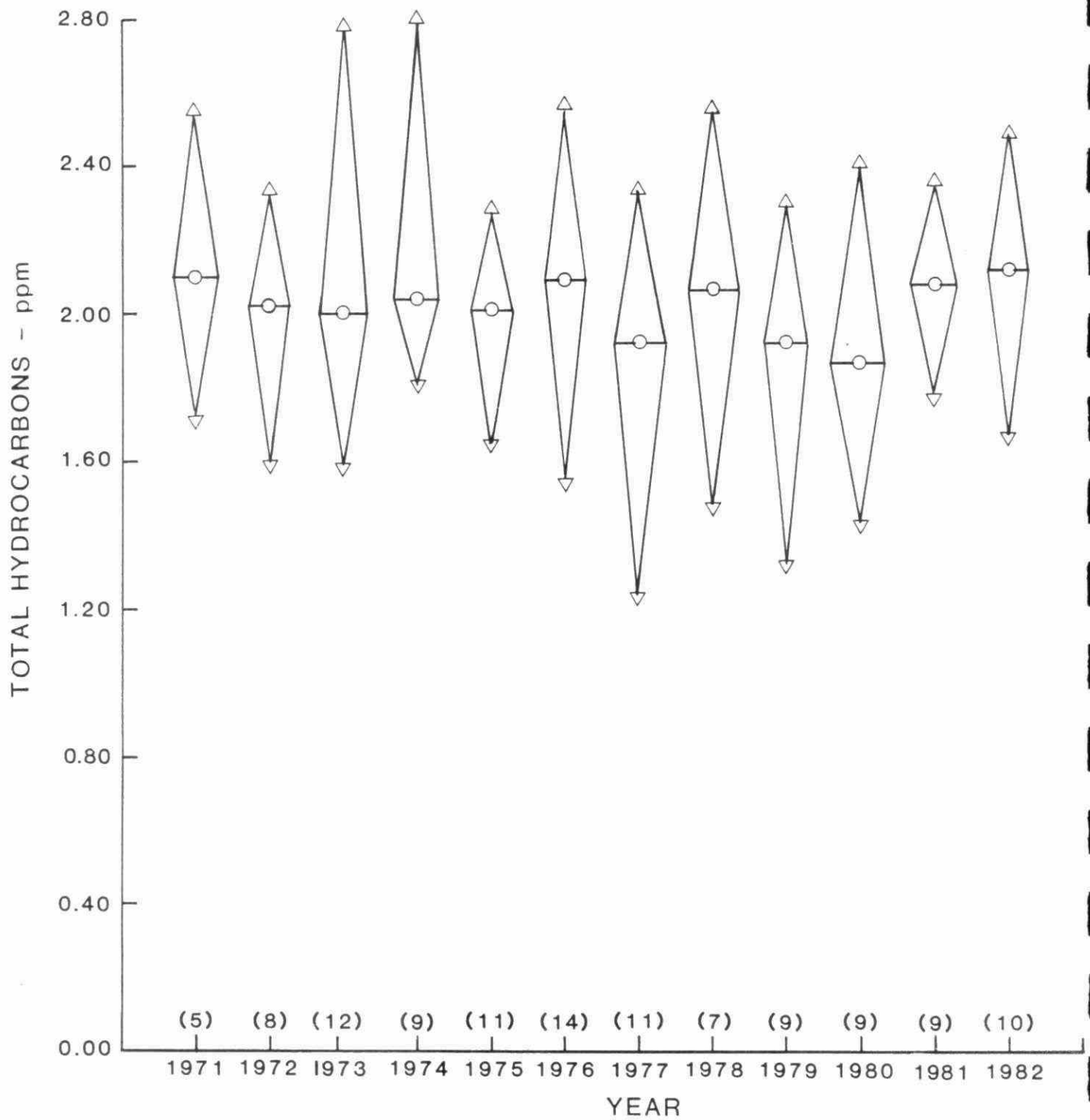


Figure 11 : Trend of Total Hydrocarbons in Ontario 1971-1982

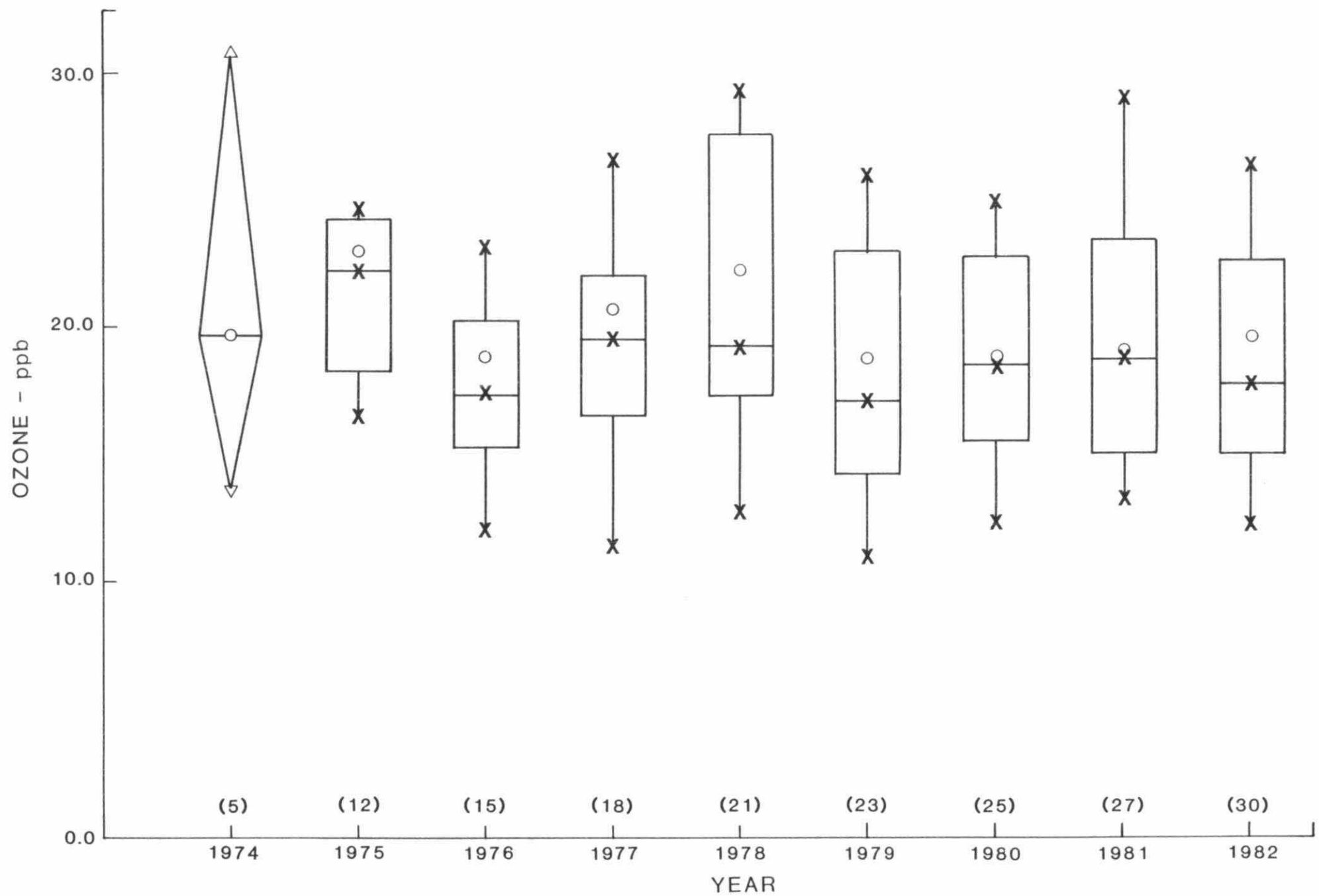


Figure 12 : Trend of Ozone in Ontario 1974-1982

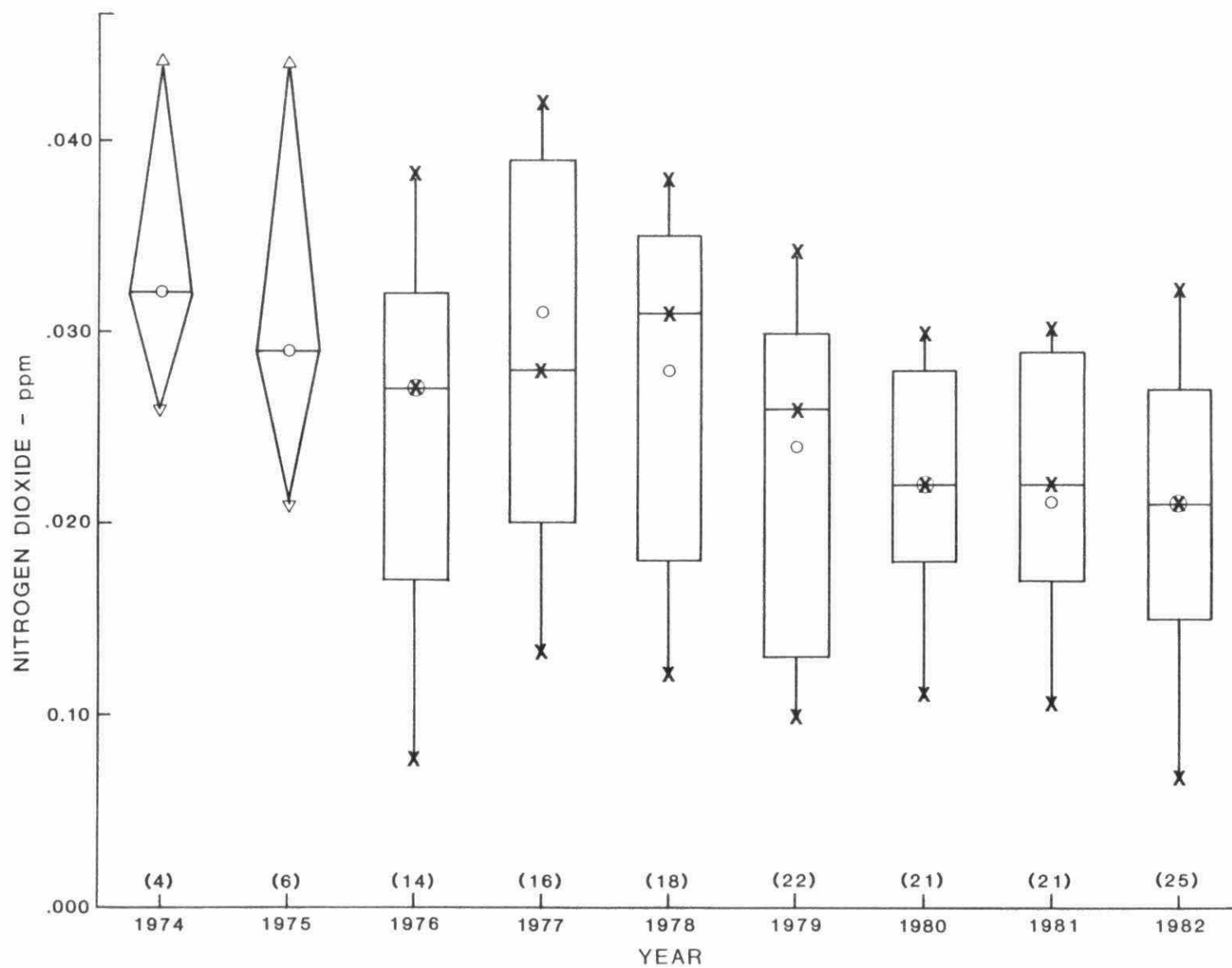


Figure 13 : Trend of Nitrogen Dioxide in Ontario 1974-1982

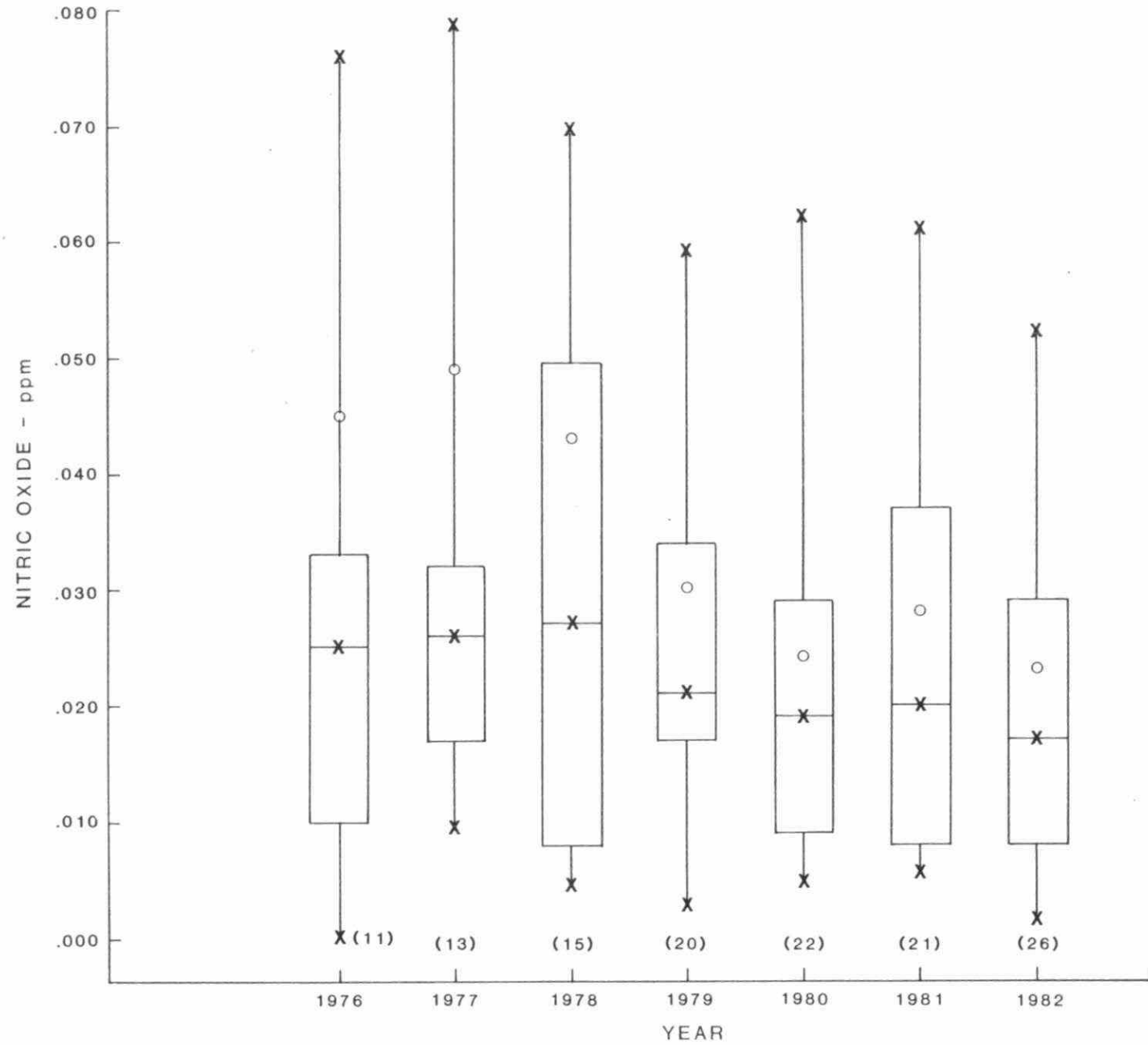


Figure 14 : Trend of Nitric Oxide in Ontario 1976-1982

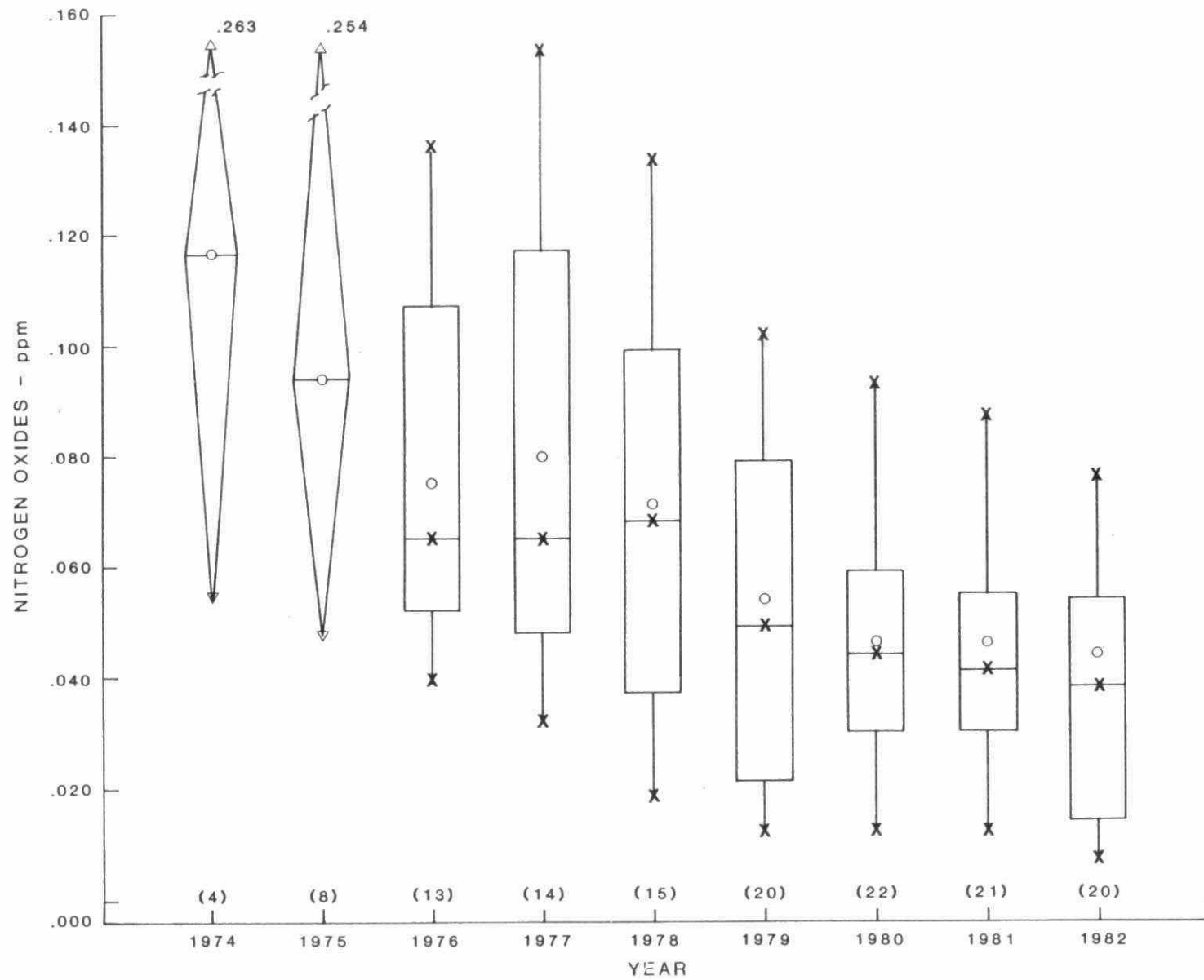


Figure 15 : Trend of Nitrogen Oxides in Ontario 1974-1982

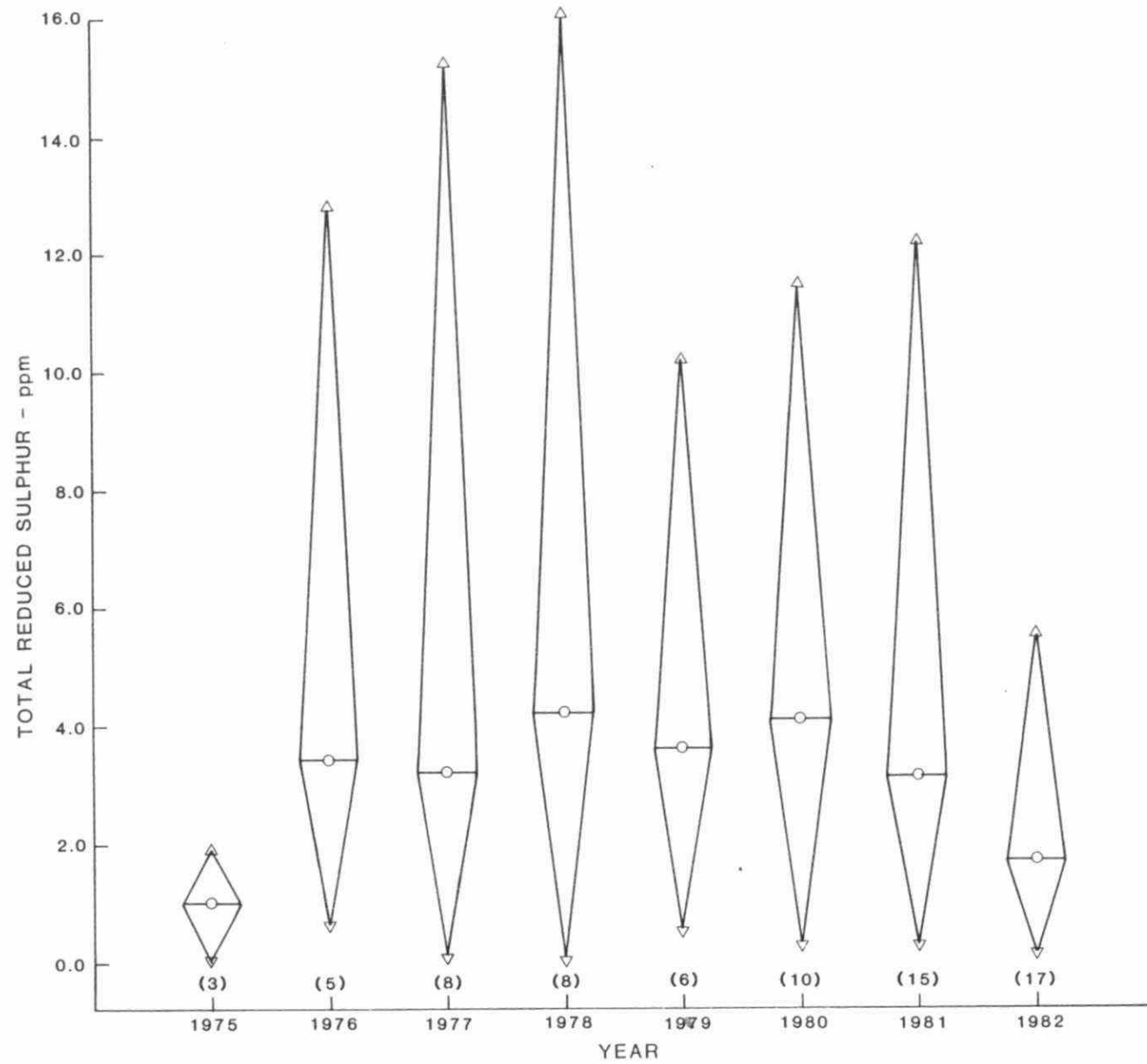


Figure 16 : Trend of Total Reduced Sulphur in Ontario 1975-1982

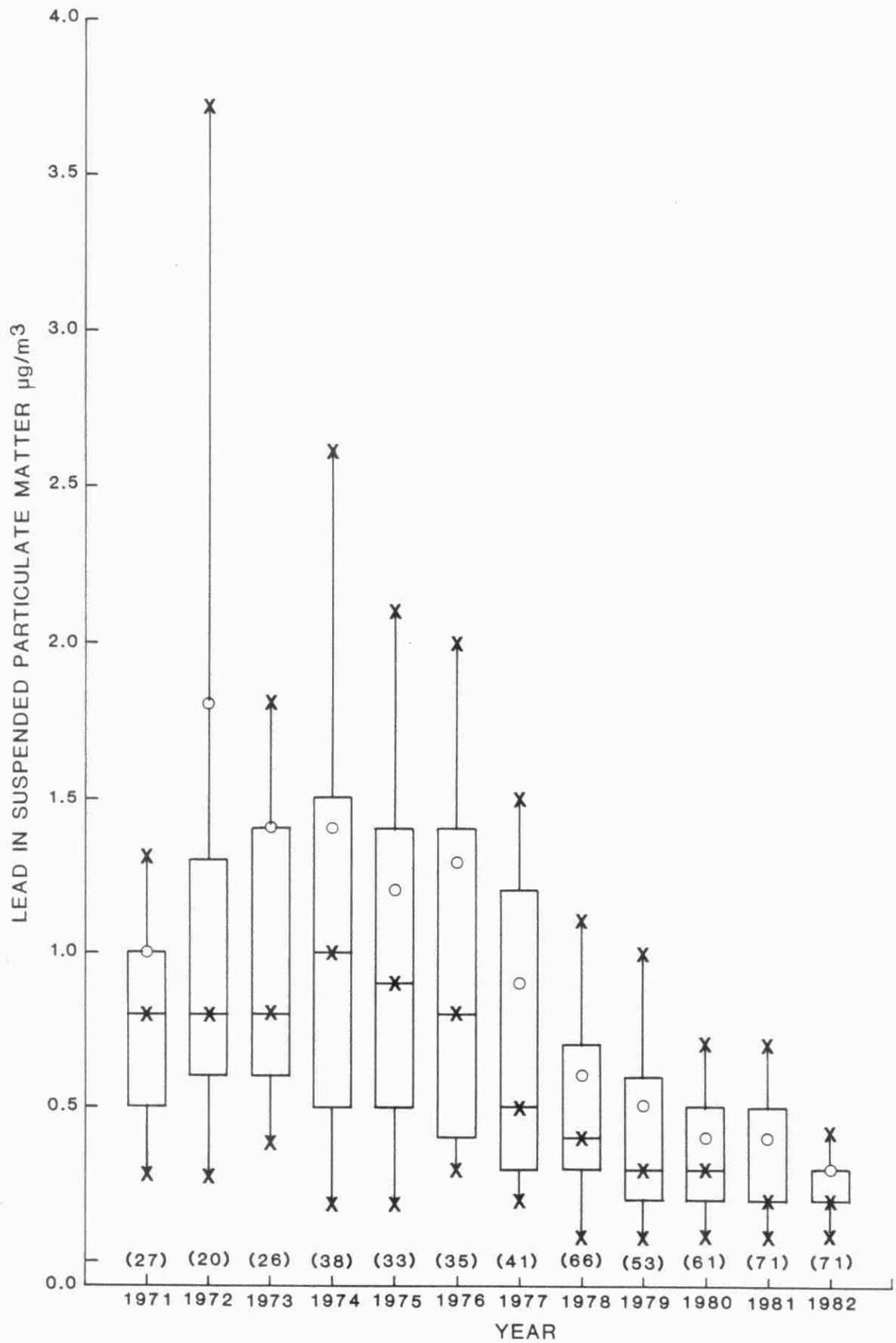


Figure 17 : Trend of Lead in Suspended Particulate Matter in Ontario 1971-1982

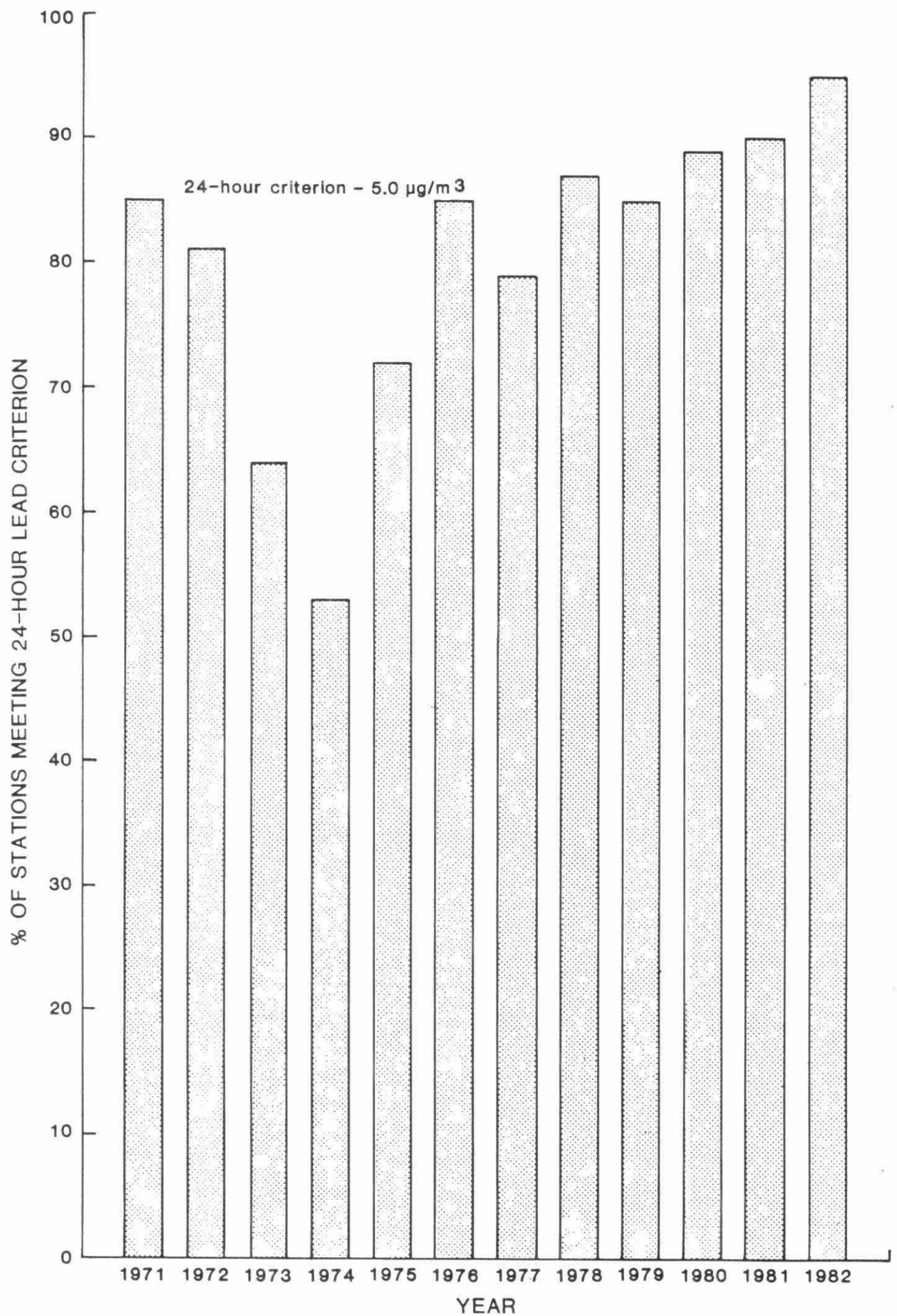


Figure 18 : Percentage of Stations Meeting Particulate Lead Criterion 1971-1982

APPENDIX

The Wilcoxon Matched-Pairs, Signed-Ranks Test

The Wilcoxon Matched-Pairs, Signed-Ranks test (hereafter referred to as the Wilcoxon test) is a non-parametric test which takes into account the magnitude of pair differences as well as their sign. Non-parametric tests are tests applied to populations having an unknown distribution or a specified distribution with a infinite number of unknown parameters. Such tests may be applied to data with nominal (qualitative) scale of measurements, an ordinal scale (ranked) of measurements, or an interval or ratio scale of measurements.

The Wilcoxon test is of high efficiency. The efficiency of statistical test is based upon the number of samples required for that test as compared to the number of samples required for a different test under similar conditions. (In comparison to its parametric equivalent, the paired - Student's test, the minimum efficiency of the Wilcoxon test is 0.864).

The Wilcoxon test is a test of high power. The power of a statistical test is based upon the probability of rejecting a false null hypothesis. Using the Wilcoxon test, it is highly probable that a false null hypothesis will be rejected. Similarly, the probability of accepting a false null hypothesis is small.

The Wilcoxon test is applied in the following manner. N data points from populations X and Y are matched and the difference between the pairs computed. The non-zero differences are then ranked without regard to sign from the smallest (Rank 1) upward to n where n equal N minus the number of pairs with zero differences. Ties are each assigned a value equal to the average of the ranks the r observations would have had if they were ranked in order, e.g., if the 2,3,4 and 5 ranking are taken by 4 observations of equal magnitude x, each x value is assigned the rank number 3.5. The rankings are then assigned the sign of the difference to which they correspond. The like-signed ranks are summed, and the lesser of the two sums becomes the test statistic T.

The null hypothesis is formulated to state that there is no difference between the two sets of data. This hypothesis is tested at the α significance level using T. If T is less than the critical value for a two-tailed test obtained from a table of critical values for the Wilcoxon test, then it can be said that there is a statistically significant difference between the data sets at the $(1-\alpha)$ % confidence level.

Reference: Conover, W.J., 1971: Practical Non-parametric Statistics, John Wiley and Sons, Inc., Toronto. p 203-215.

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